4. EVALUATION OF INVENTORY ENTRIES FOR CONTAMINANTS WITH UNKNOWN QUANTITIES

4.1 Introduction

Section 3 presents the rolled-up results of the inventory compilation for radiological and nonradiological contaminants. Most of the entries for individual contaminants identified in individual waste streams had an associated quantity in which some confidence could be placed. Such entries were summed to produce the values in the Section 3 tables.

Several other contaminant entries were identified for which reliable estimates of the quantities were not possible. Even though there was generally strong evidence of the presence of the contaminant, insufficient information was available to the data gatherer to support a reliable estimate of the quantity. The contaminant quantities for such entries were listed as unknown in the Section 3 tables.

It is desirable to have a general idea of the magnitudes of the unknown quantities. Although the magnitudes of the unknowns cannot be known reliably, an inexact estimate or upper limit is useful for comparisons with the known quantities. Comparing the inexact estimates or upper limits of the unknown quantities with the best estimates of the known quantities gives a partial indication of the completeness of the inventory.

This section presents reasonable upper-limit estimates (not 95% confidence upper bounds on the best estimates), where possible, of nonradiological contaminants with quantities listed in CIDRA entries as unknown. These estimates are then compared with the best estimates of the known entries for the same contaminants.

For the unknown quantities of contaminants in the waste streams from the RFP, a somewhat different method was used. Section 4.2 explains this method.

Only CIDRA entries with unknown quantities of nonradiological contaminants were evaluated in detail. There are also a few entries in CIDRA with unknown quantities of radiological contaminants. However, several of these radionuclides have half-lives of less than 1 year; because they have been buried for more than 10 years, their activity is now negligible. The long-lived radionuclides Tc-99, Th-232, I-129, and Co-60 also exist in unknown quantities in some waste streams. However, because either the total volume of the waste stream is very small or the activity of their scaling radionuclide is small, the unknown activities can be discounted as negligible by comparison with other entries for the same radionuclide. Cesium-137 and C-14 also appear in unknown quantities, but the data sheets list them as being present in trace amounts. Thus, the unknown quantities of radiological contaminants are expected to be so small as not to justify further bounding analysis.

The results of the evaluation of the unknown quantities are not incorporated into CIDRA because of their lower reliability.

4.2 Approach

A CIDRA printout was generated that lists every inventory entry with an unknown quantity for any nonradiological contaminant in any waste stream.

The list was used to address two types of situations. In the first situation, all entries for a given contaminant indicate that the quantity is unknown. In the second situation, one or more entries list the quantity as unknown, whereas the same contaminant is listed with a known quantity in a different waste stream. The second situation was addressed because, with additional investigation, the unknown quantity could prove to be of comparable size or even larger than the known quantity.

The detailed data forms were reviewed for each unknown entry. As necessary, the preparer of the data form was contacted and any pertinent references cited on the data form were reviewed.

One additional type of situation was encountered. On a very few data forms, information was found in footnotes and descriptive fields that discussed contaminants not listed among the inventory entries in Part C because of the sparsity of details. With the addition of certain assumptions, such information could be used to estimate quantities of contaminants. This information was pursued in a similar manner to that discussed previously.

Because, by definition, no direct methods were available for estimating the quantities for the unknown entries, indirect methods, bounding estimates, and conservative assumptions were used to develop reasonable upper-limit estimates. For example, in many cases the volume of the waste shipment was known, and volumes of other items known to be present in the shipment were subtracted to obtain a reasonable upper-limit estimate of the unknown quantity of the contaminant.

For several contaminants, the upper-limit quantity in one stream was much larger than the amounts expected in other streams. An overall upper limit could be estimated based on knowledge of the one stream without having detailed knowledge of the amounts in the other streams.

For unknown quantities of contaminants in waste streams from the RFP, a somewhat different approach was used. Much of the waste from non-RFP generators tended to be shipment oriented. That is, the waste typically consisted of a relatively large number of individual, unique, one-time shipments, each of which was comparatively small in volume. Upper-limit estimates for unknown quantities of a contaminant in a given shipment could often be made based on the volume of each shipment. By contrast, the RFP waste tended to be process oriented. That is, the waste typically consisted of a relatively small number of types of waste, with very large volumes of each type. For example, thousands of nearly identical containers of first-stage sludge were shipped. The RFP waste was not amenable to the method of using shipment volumes and subtracting the volumes of known substances to obtain a reasonable upper limit for the unknown quantity of a contaminant. In addition, estimating an upper limit on the unknown quantity of a contaminant in one container of a given RFP waste stream, then multiplying by the very large number of containers in the waste stream, could lead to estimates of contaminant quantities that are unrealistically high. Therefore, for the RFP waste, the estimates for the unknown quantities of contaminants are generally best estimates rather than upper-limit estimates.

For some contaminants in some streams, no additional useful information was located to develop a reasonable upper limit or best estimate for the quantity. Such quantities remain wholly unknown.

The evaluation discussed in this section dealt only with contaminant quantities considered by the data gatherers to be unknown (i.e., no reliable estimates were possible). Therefore, the results presented here are less reliable than those for contaminant entries with known quantities. These results are useful only for rough comparisons.

Most of the results presented here for unknown quantities of contaminants are reasonable upper-limit quantities. (In the case of waste from the RFP, best estimates are generally presented.) The actual magnitudes of the unknown quantities of contaminants are probably much smaller. Thus, the nature of these comparisons generally presents the magnitude of the unknown quantities in the worst possible light (i.e., conservatively large). Exceptions to this situation occur in the case of some contaminants for which no estimates are possible for the (potentially large) quantities in certain streams. Examples are lead and asbestos.

4.3 Results

The detailed results of the evaluation of the unknown quantities are compiled in Appendix D. For each contaminant with one or more unknown entries, the designator is given for all waste streams containing unknown quantities of the contaminant. Next is a discussion of the attempt to estimate an upper-limit quantity (or, in the case of RFP waste, a best estimate). The last column of the table in Appendix D compiles the results for all unknown entries of that contaminant.

Table 4-1 compares the upper-limit estimates of the unknown quantities from Appendix D with the best estimates of the known quantities for the same contaminants. In some cases, comparisons could be made. If the two values were within a factor of two, one value was said to be "somewhat" smaller or larger than the other. If the difference was between a factor of two and a factor of five, the difference was said to be "considerable." If the difference was greater than a factor of five, one value was said to be "much" smaller or larger. (Qualitative comparisons were used because the lack of reliability of the estimates for the unknown quantities makes quantitative comparisons potentially misleading.) In some cases, comparisons were not possible.

4.4 Conclusions

As indicated in Table 4-1, one or more inventory entries with unknown quantities were identified for 36 nonradiological contaminants, considering Be/BeO as one entry. For 18 of these 36 contaminants, comparisons of the unknown quantities (upper limits in most cases) with the known quantities (best estimates) were possible. For 7 of the 18 contaminants, the unknown quantities are believed to be less than the known quantities. For the other 11 of the 18 contaminants, the unknown quantities could be larger than the known quantities. These 11 contaminants are asbestos, chloroform, copper, cyanide, ethyl alcohol, magnesium, mercury, methyl alcohol, organophosphates, terphenyl/diphenyl, and toluene.

For the remaining 18 contaminants, the conclusion was as follows. Evaluating the unknown quantities resulted in new estimates for 10 of the 18 contaminants because no known quantity was

Table 4-1. Comparisons of unknown quantities of contaminants with known quantities of the same contaminants in other waste streams.

Contaminant	Known quantity (g) (best estimate)	Unknown quantity (g) (reasonable upper limit[a])	Conclusion: size of unknown quantity (upper limit[a]) compared with known quantity (best estimate)[b]
1,4-bis(5-phenyloxazol-2-yl)benzene	None	2.0E+05	An upper-limit estimate for the unknown quantity is 2.0E+05 g
3-methyl-cholanthrene	None	E+05	An upper-limit estimate for the unknown quantity is E+05 g
Asbestos	1.2E+06	2.3E+06	Somewhat larger
Benzene	None	1.2E+05	An upper-limit estimate for the unknown quantity is 1.2E+05 g
Beryllium	1.5E+07 total beryllium as metal or oxide	8.0E+06	Somewhat smaller
Beryllium oxide		(combined with beryllium, above)	
Cadmium	1.6E+06	No information to support upper-limit estimate	No conclusion can be drawn
Carbon tetrachloride	1.2E+08	2.0E+05	Much smaller
Chloroform	3.7E+01	E+07	Much larger
Chromium	1.0E+03	No information to support upper-limit estimate	No conclusion can be drawn
Copper	1.1E+02 of copper in copper nitrate	4.5E+04	Much larger
Cyanide	9.4E+02 of sodium cyanide	2.9E+03	Considerably larger
Dibutylethylcarbutol	None	5.4E+06	A best estimate for the unknown quantity is 5.4E+06 g
Diisopropyl-fluorophosphate	None	<<E+05	An upper-limit estimate for the unknown quantity is <<E+05 g
Ether	None	No information to support upper-limit estimate	No conclusion can be drawn
Ethyl alcohol	2.2E+04	7.1E+07	Much larger
Hydrofluoric acid	7.6E+06	2.2E+06	Considerably smaller
Lead	5.8E+08	2.0E+07	Much smaller
Lithium hydride	None	There is no firm evidence that lithium hydride was disposed of in the SDA	There is no firm evidence that lithium hydride was disposed of in the SDA
Lithium oxide	None	No information to support best estimate	No conclusion can be drawn

Table 4-1. (continued).

Contaminant	Known quantity (g) (best estimate)	Unknown quantity (g) (reasonable upper limit[a])	Conclusion: size of unknown quantity (upper limit[a]) compared with known quantity (best estimate)[b]
Magnesium	9.0E+06, plus additional 1.4E+05 of magnesium fluoride	2.8E+05 magnesium metal plus 2.8E+08 of magnesium oxide	Much larger
Manganese	None	E+04	An upper-limit estimate for the unknown quantity is E+04 g
Mercury	4.7E+05 of mercury in mercury nitrate monohydrate	1.2E+06	Considerably larger
Methyl alcohol	2.2E+05	2.8E+05	Somewhat larger
Nickel	2.2E+03	No information to support upper-limit estimate	No conclusion can be drawn
Nitric acid	5.0E+07	2.3E+06	Much smaller
Nitrobenzene	None	No information to support best estimate; the quantity is unknown—trace	No conclusion can be drawn
Nitrocellulose	None	6.8E+06	A best estimate for the unknown quantity is 6.8E+06 g
Organic acids (assumed to be ascorbic acid)	None	7.1E+07	A best estimate for the unknown quantity is 7.1E+07 g
Organophosphates	1.0E+06 of tributylphosphate	5.4E+06, assumed to be tributylphosphate	Much larger
Polychlorinated biphenyls	None	2.4E+03	A best estimate for the unknown quantity is 2.4E+03 g
Sodium	6.8E+04	1E+02	Much smaller
Sodium nitrate	3.6E+09	4.5E+05	Much smaller
Sodium-potassium	1.7E+06	No information to support upper-limit estimate	No conclusion can be drawn
Terphenyl/diphenyl	4.5E+05 terphenyl, no diphenyl	5.9E+08 g for terphenyl; 1.8E+08 g for diphenyl	Much larger
Toluene	1.9E+05	2.0E+05	Somewhat larger

Table 4-1. (continued).

Contaminant	Known quantity (g) (best estimate)	Unknown quantity (g) (reasonable upper limit[a])	Conclusion: size of unknown quantity (upper limit[a]) compared with known quantity (best estimate)[b]
Versenes [assumed to be ethylenediaminetetraacetic acid (EDTA)]	None	7.1E+07	A best estimate for the unknown quantity is 7.1E+07 g

a. As explained in the text, for waste from non-RFP generators, the estimates of the unknown quantities of contaminants are generally upper-limit estimates; for waste from the RFP, the estimates are generally best estimates. The details given in Appendix D indicate which generators produced the various fractions of the quantities of each contaminant. If the RFP was the greatly dominant contributor of the unknown quantities of the contaminant, the estimate is called a best estimate. Otherwise, the estimate is called an upper-limit estimate.

b. If the two values were within a factor of two, one value was said to be "somewhat" smaller or larger than the other. If the difference was between a factor of two and a factor of five, the difference was said to be "considerable." If the difference was greater than a factor of five, one value was said to be "much" smaller or larger.

listed. (Alternatively, one could say that the known quantity was zero and that the unknown quantity, therefore, exceeded the known quantity.) For the final 8 of the 18 contaminants, no comparisons were possible because insufficient information was available to make even a reasonable upper-limit estimate.

Although the results presented here are not totally reliable, they do provide an essential perspective on how large the quantities of contaminants might be in the unknown entries, compared with those in the known entries. This information is also one qualitative measure of the level of confidence in the contaminant inventory.

5. DATA UNCERTAINTY: SOURCES AND METHODS FOR ESTIMATING

5.1 Purpose

Two primary objectives of this task were to (1) estimate the total quantity of each contaminant disposed of in the SDA during the years 1952 through 1983 and (2) attach uncertainty bounds to these total quantity estimates. Section 3 reports the results.

This section explains the approach to and results of the uncertainty-estimation process that led to the upper and lower bounds of the contaminant quantities. This section also discusses data uncertainties that led to corrections in best estimates because of biases.

Section 5.2 provides a brief, nontechnical summary of the approach. Section 5.3 addresses the applicable requirements. Section 5.4 discusses uncertainties and biases and how they were addressed.

5.2 Summary

Section 5 presents the statistical methods for obtaining best estimates of the contaminant quantities in waste buried in the SDA during the years 1952 through 1983 and the uncertainties in the best estimates. The equations that are developed allow the construction of upper and lower bounds on the quantity of a contaminant in the waste.

The analysis of historical documents and data uncovered a significant upward bias that can occur in estimating radioactivities in waste. This bias is in the G-M counter survey method used to assay much of the waste. The value of the upward bias is a factor of 2. Therefore, where appropriate, the best estimates were corrected for this bias. The corrections are presented in the following sections.

In addition to the bias, several sources of uncertainty exist in the best estimate that also must be estimated to construct upper and lower bounds on the actual quantity. The major sources identified and estimated include error in the G-M method bias correction, error in the G-M method, error because of using scaling factors when estimating radionuclide distributions, and random error. Depending on the situation, only a subset of these uncertainties is applicable.

Using standard error propagation techniques (NCRPM 1985), the applicable uncertainties are combined to produce an overall uncertainty in the best estimate, thus, allowing for construction of upper and lower bounds on the actual activity.

This bias does not apply to estimates of the quantities of nonradiological contaminants in the waste. Bounds on these quantities were established by more straightforward methods as described later in this section.

5.3 Requirements Concerning Uncertainty Estimates

According to the EPA's *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA 1992), one of the most important inputs for a risk assessment is the concentrations of the

contaminants. EPA (1992) recommends that an average concentration be used. It also states that, because of the uncertainty associated with estimating the true average concentration at a site, the 95% upper confidence limit (UCL) of the arithmetic mean should be used. In the absence of data necessary for estimating UCLs, a value other than the 95% UCL can be used if the risk assessor can document that high coverage of the true population mean occurs, i.e., the value equals or exceeds the true population mean with high probability. While the guidance deals with contaminant concentrations, it can be applied equally well to contaminant quantities, which are the product of the HDT.

Many sources of uncertainty are inherent in quantifying the contaminant inventory of a waste site as complex as the SDA; some of them are quite large. It is not realistic to think that the total amount of each contaminant can be estimated statistically, especially in the absence of sampling, and that rigorous 95% confidence limits can be constructed. Therefore, the approach for estimating the contaminant inventory must be based on the second recommendation in EPA (1992). That is, a value other than the 95% UCL, but analogous to it, will be provided with reasonable justification that it provides coverage of the true total amount with high probability.

5.4 How Uncertainties and Biases Were Addressed

5.4.1 Background

The waste buried at the SDA during the years 1952 through 1983 originated from several generators over various time periods and consisted of many different types. Figure 5-1 depicts the steps in the waste handling process, from waste generation to disposal. The three boxes within the dashed oval are the steps that contribute to the uncertainty in the reported contaminant quantities in a shipment.

The step represented by the first box within the uncertainty oval is the measurement of radioactive waste volumes and radionuclide activities in the shipment. The uncertainty in the estimate is due to many sources of error in this measurement process. The measurement process depends on the type of waste being shipped and the waste generator.

The second box in the uncertainty oval pertains to the nonradioactive contaminants in the waste. Nonradiological contaminants were, at best, identified on shipping records as being part of a shipment to the SDA. A formal process for measuring and reporting nonradiological contaminants did not exist at that time, and quantities were generally not reported on shipping records. Therefore, estimating total quantities and uncertainties for the HDT was often based on sources other than the shipping records, e.g., process knowledge and interviews with personnel acquainted with the processes that produced specific waste streams. A major source of uncertainty is the incompleteness of the available information, which tends to underestimate the total quantities.

The third box in the uncertainty oval addresses recording the measurements on shipping records and transferring the information to the RWMIS database. Errors associated with transcription, summarization, interpretation, radionuclide distributions, and upper-limit reporting result in additional uncertainty in the reported total quantities of contaminants.

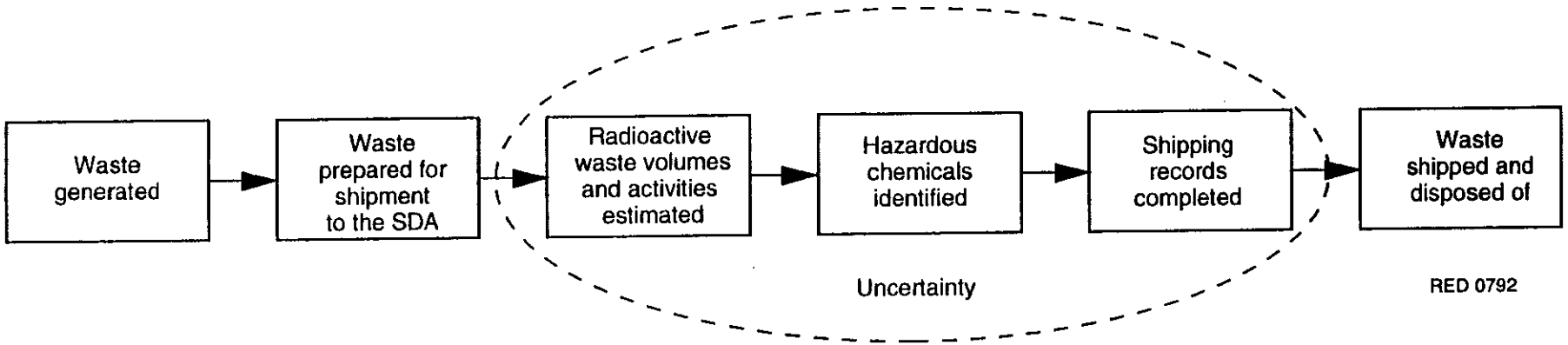

Figure 5-1. The process from waste generation to disposal.

As discussed in Section 2, a data form was filled out for each waste stream to record the knowledge gained in the information search. An important part of this process was identifying major sources of uncertainty. As mentioned previously, the contaminant-measurement process is dependent on the general type of waste. Furthermore, the generators used different processes and uncertainties differed in each step of the processes. The following subsections discuss the uncertainties.

5.4.2 Biases and Corrections for Radiological Data Originally Obtained by the Geiger-Müller Counter Survey Method

The minority of waste streams or waste shipments used sampling, other direct methods, or nuclear physics calculations to estimate radioactivity at the time of shipment. However, the majority of shipments used an indirect method at the time of shipment to estimate the radioactivity in a container of waste. The indirect method is a major source of uncertainty in estimates of radionuclide quantities for these generators. The specific method used since the 1950s is referred to here as the G-M counter survey method, or the G-M method. Another related source of uncertainty is that specific radionuclides are not identified in individual waste containers. These two sources of uncertainty are discussed in this section and in Section 5.4.3 in detail because of the large potential effect on the estimated radionuclide inventory.

The G-M method consists of taking radiation readings on each of the five exposed sides of a waste container using a calibrated G-M survey meter, averaging the readings, and multiplying by a constant number to convert the average radiation reading to the estimated radioactivity in curies. Several sources of uncertainty are inherent in this process: (a) the geometric position of the radiation source in the container, (b) the type of radiation from the particular radionuclides present in the container, (c) the density of the materials within the container (termed the "fill matrix"), and (d) the error in the survey meter itself.

Three documented studies (Simpson et al. 1982, Hartwell et al. 1987, and Hartwell and Thompson 1988) have explored the adequacy of the G-M method as applied to INEL waste containers. Although the studies involved only low-radiation-level containers, the results are believed to be generally accurate for higher-radiation-level containers.

The position of the source in the container appears to be a particularly large contributor to the uncertainty. According to Simpson et al. (1982), an upward bias of at least 50% (compared with more rigorous methods, such as gamma-ray spectrometry) was measured when a known MFP test source was located at the center of a mock-up waste box. (The G-M method was derived originally from theoretical considerations for steel waste dumpsters, but it was applied to many kinds of waste boxes.) When the source was located away from the center of the box, biases as large as 8,500% were measured for unusual situations. Simpson et al. (1982) concluded that the G-M method is highly susceptible to overestimating the actual curie content because of "hot spots" located near a container side and the small detector-to-source distance.

Simpson et al. (1982) also noted that results using the G-M method depended on the radionuclides present in the container, compared with the radionuclides used in developing and calibrating the method. For example, if the radionuclide in the container were Co-60 and if 0.7-MeV gammas had been assigned for conversion of the radiation readings to the estimated radioactivity, the effect could be overestimation by a factor of 2 (USHEW 1970).

Another significant contributor to the uncertainty is the density of the waste container fill matrix. This contributor includes both self-shielding within the source and shielding because of other materials within the container. Hartwell et al. (1987) investigated this effect and concluded the actual curie content is underestimated even at very slight attenuation. As the fill matrix density increases, the attenuation increases, and the underestimation becomes more severe. The conversion calculation from radiation reading to curies assumes that the container offers very slight attenuation. Thus, the conversion does not account for this problem. Tests conducted on various densities of fill matrix (Hartwell et al. 1987) indicated underestimates using the G-M method ranging from approximately -90% to -50% (i.e., factors of one-tenth to one-half) of the known actual value. Because the safety of the people handling the waste was a primary consideration, it is reasonable to assume that the fill matrix density was purposely increased to provide additional shielding protection. Interviews have confirmed this assumption, which further inflates an already significant negative bias.

Interviews with health physics personnel indicated that, during the early years, the random error in the survey meter was ±20%. After approximately 1976, improvements in the calibration of the meters reduced this error to ±10%.

Because of the highly variable (shipment-dependent) nature of the sources of the above uncertainty estimates, a statistically rigorous propagation to an overall uncertainty was not feasible. However, by combining professional judgment, reasonable assumptions, and standard statistical techniques, defendable bounds on actual quantities could be determined. These bounds are analogous to 95% confidence limits and represent "reasonable certainty" that they contain the true value. The following paragraphs describe the rationale used in arriving at estimates of the bias and the random error in the G-M method.

Uncertainty in the G-M method because of source position is a positive bias ranging from 50% to 8,500%, depending on the position of the source. The closer the source is to a face of the container, the more severe the bias. Typically, the contamination is not concentrated in a small volume of the container, but rather it is distributed throughout the container. A reasonable assumption is uniform distribution throughout the container. If we also assume that the bias increases (according to the inverse of the source-to-detector distance squared) from 50% to 8,500% as the source is moved from the center of the container to a face, the resulting average bias because of source position for a uniformly distributed source is approximately 1,050%, or 11.5 times the true value.

As stated previously, the bias because of density of the fill matrix ranges from -50% to -90%, depending on the density, based on measurements of mock-up containers with known sources and fill materials ranging from air to stacked paper (specific gravity approximately 0.8) (see Hartwell et al. 1987). The majority of the waste containers during the time period of interest would be expected to have effective fill densities no more than that of stacked paper. (This observation is based on a review of data for waste generated more recently and the fact that container packing density has increased over the years.)

The combined bias because of source position and fill density was evaluated as follows. Based on the data described above, the largest value that could be used for the combined bias is 8,500% (a factor of 86) for source location and -50% (a factor of 0.5) for fill density, which yields a product of 4,200% (a factor of 43). The smallest value that could be used for the combined bias is 50%

(a factor of 1.5) for source location and -90% (a factor of 0.1) for fill density, which yields a product of -85% (a factor of 0.15). However, these extreme values reflect highly unusual situations, such as a waste container in which a point source of radiation rests against one inner face of the container and nothing else except air is inside the container.

A more realistic set of limits on the bias was developed by assuming a uniformly distributed radiation source within the waste container. As stated above, the average bias because of source position in this case is 1,050% (a factor of 11.5). The same range of fill densities as above was retained. Thus, the largest realistic value that could be used for the combined bias is 1,050% (a factor of 11.5) for source location and -50% (a factor of 0.5) for fill density, which yields a product of 475% (a factor of 5.75). The smallest realistic value that could be used for the combined bias is 1,050% (a factor of 11.5) for source location and -90% (a factor of 0.1) for fill density, which yields a product of 15% (a factor of 1.15). A midpoint value for the combined bias is 1,050% (a factor of 11.5) for the source location and -70% (a factor of 0.3) for fill density, which yields a product of 245% (a factor of 3.45). This is the best estimate for the value of the bias. To be somewhat conservative, however, a combined bias of 100% (a factor of 2) was used for these two factors. In other words, ignoring variability because of error in the survey meter, the actual radioactivities are expected to be approximately one-half of the value of the reported measurements using this method.

The studies documented in Hartwell and Thompson (1988) and Simpson et al. (1982) include the measurements of numerous waste containers using the more accurate gamma-ray spectrometry method and the G-M method. In all cases, the G-M method resulted in measurements exceeding those of the gamma-ray spectrometry method by percentages ranging from 10% to 3,500%. This lends some confirmation to the conservative estimate of the positive bias of a factor of 2 and to the range of realistic combined biases derived above.

While the actual energy of the radiation from the radionuclides in a waste container is definitely a contributor to error in the reported activities, it was not included in the bias correction because a large portion of the inventory is near the assumed energy level of 0.7 MeV. Radionuclides of higher energy exist in substantial quantities as well, but their effect on the bias is to further overestimate the total quantities. To be conservative, this effect was ignored.

Thus, if the radioactivity in a waste stream was originally estimated using the G-M method, the reported estimates of total radionuclide quantities for specific years were divided by 2 to correct for these biases and to arrive at a best estimate. This correction is an approximation because of the large numbers and varieties of waste streams and radionuclides involved. However, use of the correction is believed to result in a more accurate inventory than use of the uncorrected G-M counter readings.

The random error because of the G-M survey meter was conservatively assumed to be $\pm 20\%$ for all radioactivity estimates believed to have been developed using the G-M method during the time period of interest. The total random error, including the uncertainty in the bias correction, is developed in Section 5.4.5.

As stated previously, for certain waste streams, the data gatherers used records of direct measurements, personal knowledge, interviews, and nuclear physics calculations to arrive at a sound

judgment on the uncertainty in their reported total quantities. In these cases, the data gatherers' uncertainty estimates were used to determine upper and lower bounds on the total quantities.

There are some exceptions to the approaches described above. These exceptions occurred when (a) the data gatherer lacked sufficient information to provide uncertainty estimates in the reported total quantities, and (b) the bias correction for the G-M method was not applicable. The bias correction is not applicable for radionuclides emitting weak gamma rays or no gamma rays.

If uncertainty information does not exist in the appropriate data fields for the bounds on radionuclide quantities, CIDRA automatically calculates upper and lower bounds (see Section 5.4.5) after correcting for the G-M method bias by dividing the reported estimate by 2. To ensure that these automatic calculations are not performed erroneously for radionuclides that emit very little or no gamma radiation, each waste stream was checked manually for these potential occurrences. Where there was any indication that the G-M method was not used for the radionuclides in question, estimates for the upper and lower bounds were provided to ensure that the G-M method correction was not applied.

The following paragraphs discuss some additional considerations that apply in developing the uncertainties for waste from NRF and ANL-W.

Because high-energy-emitting Co-60 was the principal radionuclide of interest at NRF, the survey meters were typically calibrated using high-energy radiation. This adds some uncertainty in the measurement when the container holds large quantities of radionuclides emitting low-energy radiation (e.g., Fe-55 and Ni-63). These uncertainties, however, are not considered to be any more significant than other assay uncertainties. Therefore, the bias and uncertainty estimates described in this section were also applied to most of the waste from NRF. The exception was the scrap core structural material shipped from ECF in scrap casks.

In a letter dated February 27, 1989 (Bartolomucci 1989), the manager of ECF Engineering at NRF informed EG&G Idaho that the past method for estimating radioactivity, or curie content, for scrap casks was in error. The letter provided revised curie content estimates, and these revised estimates were subsequently incorporated into the RWMIS database. Bartolomucci (1989) did not, however, assign uncertainty limits to the estimates.

Another letter issued by NRF (Nieslanik 1994) applied an accuracy of +10% and -30% to scrap cask activity calculations, taking into consideration incomplete content data on some cores when received, approximations that deleted radionuclides contributing less than 1% to the total activity, and assumptions that had to be made regarding radioactive flux and core life.

The method used by NRF to arrive at radioactivity estimates for the scrap cask shipments was based on knowledge of the metal alloys in the reactor core structural materials and reactor core radiation history. This information allowed NRF to calculate the extent of expected neutron activation of the core structural material. This activity was then decayed for the length of time from the end of reactor operation until the scrap was shipped from ECF to the SDA.

In summary, the NRF uncertainty estimate of +10% and -30% for the scrap cask estimates was used in this report; however, the bias and uncertainty estimates in this section related to the G-M method were applied to all the other waste from NRF.

Radioactivity estimates of ANL-W waste generated after 1970 were made at the time of shipment using a refined G-M counter method. The method factored in the type of waste container and other information. This method is considered more reliable than the typical G-M counter method, which was used by all generators listed previously. Therefore, upon the advice of ANL-W technical personnel, no bias correction was applied to ANL-W waste activity measurements made beginning in 1971. The random error was specified by ANL-W personnel to be ±25% for such measurements.

For all generators, the CIDRA database lists the radionuclide quantities (including the effects of the G-M correction, if any) as the "best estimates." The uncorrected quantities are also available from CIDRA and are called the "reported estimates."

5.4.3 Scaling Factor Uncertainties for Radiological Data

Another significant source of uncertainty is due to the use of scaling factors for estimating radionuclide distributions. In fact, based on the following analysis, it appears to be the dominant source of uncertainty in estimates of the total activity of many radionuclides.

A scaling factor is a fraction or percentage representing the activity of one radionuclide relative to the activity of another radionuclide or to the total activity of a group of radionuclides. Scaling factors were used to estimate the activities of several difficult-to-measure radionuclides in waste shipments to the SDA. For example, suppose the total activity in a waste shipment is 100 Ci and the scaling factor for Sr-90 (whose activity is difficult to measure outside a laboratory) is 0.15 (15%). Then the estimated activity of Sr-90 in the shipment is 15 Ci.

Scaling factors were developed by evaluating the data from analytical laboratories possessing the capabilities to analyze the activities of these difficult-to-measure radionuclides and relating the activities to those of easily analyzed radionuclides or total sample activities.

The uncertainty in the scaling factor must be estimated and incorporated into the overall uncertainty in the radionuclide activity. The following paragraphs provide an overview of the development of the uncertainty estimates for the scaling factors. Einerson and Smith (1995) provides the details. Section 5.4.5 incorporates the scaling factor uncertainty into the overall uncertainty.

Limited INEL data exist on scaling factors for the waste disposed of in the SDA. The most comprehensive data available for other locations exist in a report prepared for the Electric Power Research Institute (EPRI 1987). That report provides the results of an extensive data collection and analysis effort, including activities of several radionuclides from various waste types and reactor types. The data most closely resembling SDA waste came from samples originating in waste from pressurized water reactors of commercial nuclear utilities.

Two basic approaches are possible for estimating the uncertainty that arises from the use of scaling factors. The first approach is to identify all of the sources of uncertainty inherent in the

process of developing and using scaling factors (e.g., analytical error or error because of the G-M survey method). These uncertainties are then propagated to obtain an estimate of the overall uncertainty attributed to the use of scaling factors. The second method is strictly empirical. This approach involves using a large data set (such as that found in the EPRI report) containing the activities of several radionuclides for several waste streams. Then, by constructing scaling factors and estimating the distributional properties, the uncertainty is empirically developed.

Because a large data set that is somewhat representative of the SDA waste streams exists in the EPRI (1987) report, the empirical approach was used here. The three basic steps were to (1) choose subsets of the EPRI radionuclides thought to best represent the radionuclides present in the SDA waste, (2) estimate the scaling factor mean, standard deviation, and relative standard deviation (RSD) (the uncertainty) for each radionuclide in this subset, and (3) apply these uncertainty estimates to appropriate subsets of the radionuclides and waste streams for the SDA waste. A subset of radionuclides from the EPRI data was selected because the analysis of every radionuclide would have added only minimal information.

The subset of radionuclides analyzed from the EPRI data included C-14, Fe-55, Ni-63, Sr-90, Tc-99, I-129, Co-60, and Cs-137. These radionuclides were selected because they represent the difficult-to-measure radionuclides present in the SDA waste and the radionuclides to which their activities are compared. Therefore, they should demonstrate the range of scaling factor uncertainties inherent in the radionuclides present in the SDA waste.

The scaling factor for a radionuclide was taken to be the ratio of the activity for the radionuclide to the total activity in the waste. The total activity in a sample was defined here to be the sum of the eight radionuclides given above and is shown in Equation (5-1). It is recognized that, in actuality, several more radionuclides may constitute the total set. However, it seems reasonable to assume that the estimate of scaling factor uncertainty will not depend on the number of radionuclides used when calculating a "total" activity as long as the set of radionuclides used is representative and fairly comprehensive.

The total activity in a sample is shown in Equation (5-1):

$$t_j = \Sigma_i a_{ij} \qquad (5\text{-}1)$$

where

t_j = total activity for sample j

a_{ij} = activity of radionuclide i for sample j.

Then for each sample and each radionuclide used in this analysis, a scaling factor can be written as

$$w_{ij} = a_{ij}/t_j \qquad (5\text{-}2)$$

where

w_{ij} = scaling factor for radionuclide i and sample j.

The uncertainty referred to above is in terms of the RSD, which is defined as the standard deviation divided by the mean. Therefore, the next step in the analysis was to estimate the mean, standard deviation, and RSD of the scaling factors for each radionuclide across all samples for waste from pressurized water reactors in EPRI (1987). The results are presented in Table 5-1, along with the number of samples comprising the estimates.

Logical groupings of RSD values are apparent from the results in Table 5-1. The scaling factor RSDs for Fe-55, Ni-63, Co-60, and Cs-137 are 0.9, 1.0, 0.7, and 1.1, respectively. The scaling factor RSDs for C-14, Sr-90, I-129, and Tc-99 are 3.4, 4.8, 3.7, and 4.4, respectively. Based on these results, two values of the scaling factor RSDs, 1 and 5, were chosen for application to the uncertainty estimates for the radionuclides in the SDA waste that involved the use of scaling factors. These values of 1 and 5 were chosen based on simplicity and conservatism. While it would have been possible in theory to estimate a separate RSD for each of the approximately 100 radionuclides, the effort was not warranted considering the limited additional accuracy obtainable and the limited data available.

As described in Einerson and Smith (1995), the uncertainty in the scaling factors also depends on the particular waste stream in which the radionuclide exists because the method of estimating the activity of a given radionuclide sometimes varied from stream to stream. Thus, the radionuclides in the SDA waste can be placed into three groups corresponding to the three possibilities of scaling factor uncertainty: RSDs of 0, 1, and 5. An RSD of 0 occurs for those radionuclides for which scaling factors were not used in determining their activity.

Table 5-2 presents the scaling factor uncertainty used for each of the radionuclides when incorporating this uncertainty into the overall uncertainty of the total activities. Einerson and Smith (1995) presents the rules for applying scaling factor uncertainties, as well as some exceptions to Table 5-2 based on the method used to estimate the distribution for each waste stream.

Unless excluded by either or both considerations related to an RSD of 0 or an excluded waste stream, the scaling factor uncertainty was added to the other identified uncertainties whether or not the data gatherer had listed upper and lower bounds for the radioactivity entry on the datasheets.

Table 5-1. Scaling factor relative standard deviations for EPRI (1987) data.

Ratio	Number of samples	RSD
C-14/total	273	3.4
Fe-55/total	268	0.9
Ni-63/total	280	1.0
Sr-90/total	234	4.8
Tc-99/total	30	4.4
I-129/total	20	3.7
Co-60/total	333	0.7
Cs-137/total	241	1.1

Table 5-2. Scaling factor relative standard deviations for use in the historical data task uncertainty estimate.

Radionuclides	Scaling factor RSD used in uncertainty estimate
U, Th, Ra (all isotopes of)	0
Cs-137, Co-60, Fe-55, Ni-63	1
All other radionuclides	5

One exception to the scaling factor RSDs in Table 5-2 involves waste streams NRF-618-1H and NRF-618-6H. For these streams, the scaling factor RSD for Sr-90 was taken to be a value of 1 rather than 5. This exception was based on data collected by NRF.

5.4.4 Uncertainties for Nonradiological Contaminants

For nonradiological contaminants, the main source of uncertainty is the lack of information. For some waste streams, the data gatherers obtained good estimates and associated uncertainties of the total quantities of particular contaminants. In these instances, the data gatherers' estimates were used. These estimates are for a variety of contaminants from several waste streams and can be considered a representative subset of all the nonradiological contaminants identified. The upper bounds estimated by the data gatherers ranged from 1 to 3.6 times the estimated amount, with the majority being less than a factor of 2. When lacking uncertainty information, a factor of 2, based on the data gatherer's professional judgment, was conservatively used to construct an upper bound on the quantities disposed of.

5.4.5 Best Estimates and Bounds

Each waste stream from each waste generator was identified, and annual quantities of radiological and nonradiological contaminants in the streams were estimated. In addition to these estimates of annual quantities disposed of, bounds on these estimates were calculated. While it was not possible to calculate 95% confidence limits in the standard way because of the lack of sampling and appropriate data, it was possible to arrive at reasonable and defensible bounds based on the historical information acquired and on knowledge of the sources of uncertainty described in the preceding sections.

When possible, the bounds provided represent the data gatherers' indication that, with reasonable certainty, the true annual quantities buried are contained within them. In some cases, the data gatherers' indications are based on knowledge of the particular waste stream and the measurement methods used at the time. In other cases, heavier reliance was placed on professional judgment. When professional judgment could not be made, generic error bounds were constructed by propagation of known biases and uncertainties. "Reasonable certainty" can be considered analogous

to 95% confidence; while not statistically rigorous, it represents a legitimate attempt at quantifying a very difficult parameter.

With the assumption that the bounds estimated by the data gatherers (or through propagation) represent 95% confidence limits, the following discussion presents the method used to propagate the uncertainties so that uncertainty bounds could be constructed on the total amount of a contaminant disposed of at the SDA in all waste streams.

An individual contaminant may occur in a variety of forms and in a variety of waste streams. Therefore, it may or may not be useful to group all occurrences together when estimating contaminant quantities for use in a risk assessment. Groupings of contaminant occurrences will have to be performed based on the particular objectives of the data used in the risk assessment.

After a risk assessor determines a desired grouping, all occurrences in CIDRA for which the contaminant meets the grouping specification (e.g., a particular physical form of the contaminant) are flagged. An occurrence is a single row of Part C or Part D of the data form (see Appendix A). Each row corresponds to information for one contaminant from a single waste stream for a single year (or a range of years during which the generation rate was assumed constant). A single data form is restricted to describing only a single waste stream.

After the contaminants of interest have been selected, grouped, and flagged in the database, the next step is to estimate the quantities needed by the risk assessor. These include the best estimate of the total amount of a contaminant disposed of and its upper bound (analogous to a 95% UCL) for each uniquely flagged contaminant grouping.

The best estimate for the total amount of a contaminant grouping is the sum over all waste streams and all years for that contaminant grouping, as expressed by Equation (5-3):

$$T = \Sigma_i \Sigma_j T_{ij} \qquad (5\text{-}3)$$

where

T = best estimate of the total quantity of a particular contaminant grouping disposed of

T_{ij} = best estimate of the quantity of the particular contaminant grouping disposed of from waste stream i in year j.

To construct an upper bound on T requires s_{ij}, the standard deviations of T_{ij}. In cases where analysis data or professional judgment have been used to estimate U_{ij}, the upper bound on T_{ij}, the standard deviation of T_{ij} can be estimated as given in Equation (5-4).

$$s_{ij} = (U_{ij} - T_{ij})/2, \text{ when based on analysis data or professional judgment.} \qquad (5\text{-}4)$$

When such information is not available, s_{ij} is estimated based on the biases and random error involved. For radiological contaminants, the bias was shown earlier to range from a factor of 1.15 to a factor of 5.75. Thus, a bias correction (division by the bias) would range from 0.87 to 0.17 with a midpoint of 0.5, which is the correction factor used. It is assumed that this range is an approximate

95% confidence interval on the true bias. Given this assumption, an estimate of the uncertainty s_k (one standard deviation) in the bias correction is shown in Equation (5-5).

$$s_k = \frac{\text{range of 95\% confidence interval}}{4} = \frac{0.87 - 0.17}{4} = 0.17 \quad (5\text{-}5)$$

The estimate of the uncertainty, s_X, because of random error in the G-M survey meter is 20% of the reported quantity, as given in Equation (5-6).

$$s_{X_{ij}} = 0.2X_{ij} \quad (5\text{-}6)$$

where

X_{ij} = the reported quantity of a particular contaminant grouping disposed of from waste stream i in year j.

The estimate of the uncertainty because of the scaling factor, in terms of the RSD s_w/w, depends on the specific radionuclide and waste stream, as mentioned in Section 5.4.3 and discussed in detail in Einerson and Smith (1995). The three distinct cases are RSDs of 0, 1, and 5.

Combining these uncertainties, using the method of statistical differentials (Kotz and Johnson 1988), leads to a formula for estimating the standard deviation of T_{ij}, as shown in Equations (5-7) and (5-8).

$$T_{ij} = kX_{ij} \quad (5\text{-}7)$$

where

k = the bias correction, whose value is 0.5.

$$s_{ij} = \sqrt{(kX_{ij})^2 \left[\left(\frac{s_k}{k}\right)^2 + \left(\frac{s_{X_{ij}}}{X_{ij}}\right)^2 + \left(\frac{s_w}{w}\right)^2\right]} \quad (5\text{-}8)$$

$$= T_{ij}\sqrt{0.16 + \left(\frac{s_w}{w}\right)^2}, \text{ when analysis data or professional judgement are not available.}$$

For nonradiological contaminants, a conservative estimate of half the reported quantity, based on the discussion in Section 5.4.4, is used for s_{ij} when professional judgment cannot be made.

$s_{ij} = 0.5T_{ij}$, for nonradiological contaminants when professional judgment cannot be made. (5-9)

The standard deviation s of T can then be calculated as

$$s = (\Sigma_i \Sigma_j s_{ij}^2)^{1/2} \quad . \tag{5-10}$$

Data of this type typically follow a lognormal distribution (Gilbert 1987). Therefore, it is reasonable to assume that the total activity T of a radionuclide (or total quantity of a nonradiological contaminant) is lognormally distributed with mean α and standard deviation β, where α and β are estimated by T and s. Because of the relationship between the normal and lognormal distributions (Blackwood 1992), it follows that the natural logarithm of T is normally distributed with mean μ and standard deviation σ with

$$\alpha = e^{\mu + \frac{1}{2}\sigma^2} \tag{5-11}$$

$$\beta^2 = e^{2\mu + \sigma^2}\left(e^{\sigma^2} - 1\right) \quad . \tag{5-12}$$

Solving for μ and σ and using T and s as estimates of α and β gives:

$$\mu = \ln(T) - \frac{1}{2}\sigma^2 \tag{5-13}$$

$$\sigma^2 = \ln\left(\frac{T^2 + s^2}{T^2}\right) \quad . \tag{5-14}$$

An upper bound on the total quantity for a particular contaminant grouping U can now be calculated as shown in Equation (5-15).

$$U = e^{(\mu + 2\sigma)} \quad . \tag{5-15}$$

The construction of a lower bound L on T is analogous to the upper bound and is given in Equation (5-16).

$$L = e^{(\mu - 2\sigma)} \quad . \tag{5-16}$$

The above approach cannot be considered statistically rigorous. However, with the combination of professional judgment, reasonable assumptions, and conservative approximations, there is reasonable certainty (i.e., 95% confidence) that the upper bounds derived with this approach are not exceeded.

References for Section 5

Bartolomucci, J. A., 1989, letter to J. N. Davis, "Curie Content Estimates for ECF Scrap Casks," NRFE-E-1448, Naval Reactors Facility, February 27, 1989.

Blackwood, L. G., 1992, "The Lognormal Distribution, Environmental Data, and Radiological Monitoring," *Environmental Monitoring and Assessment, 21*, pp. 193–210, 1992.

Einerson, J. J. and T. H. Smith, 1995, *Estimation and Application of Scaling Factor Uncertainties for the Historical Data Task and the Recent and Projected Data Task*, Engineering Design File ER-WAG7-62, Lockheed Idaho Technologies Company, April 1995.

EPA (U.S. Environmental Protection Agency), 1992, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, EPA Publication 928517-081, May 1992.

EPRI (Electric Power Research Institute), 1987, *Updated Scaling Factors in Low-level Radwaste*, EPRI NP-5077, Impell Corporation, March 1987.

Gilbert, R. O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, 1987.

Hartwell, J. K. and D. N. Thompson, 1988, *Investigation of a Gamma-Ray Spectrometric Low-Level Waste Measurement System: FY 1988 Activities*, ST-CS-028-88, September 1988.

Hartwell, J. K., D. N. Thompson, S. W. Duce, A. L. Freeman, 1987, *Investigation of a Gamma Spectrometric Low-Level Waste Measurement System*, ST-CS-022-87, September 1987.

Kotz, S. and N. L. Johnson (eds.), 1988, *Encyclopedia of Statistical Sciences*, Volume 8, John Wiley and Sons, New York, pp. 646–647, 1988.

NCRPM (National Council on Radiation Protection and Measurements), 1985, *A Handbook of Radioactivity Measurements Procedures*, NCRP Report No. 58, 2nd ed., February 1, 1985.

Nieslanik, R. W., 1994, letter to T. H. Smith, "NRF Comments to the Radioactive Waste Management Complex (RWMC) Waste Inventory Report," NRFEM-RR-1122, Naval Reactors Facility, March 29, 1994.

Simpson, O. D., L. D. Koeppen, E. D. Cadwell, 1982, *Solid Waste Characterization Study at TRA*, RE-P-82-121, EG&G Idaho, Inc., December 1982.

USHEW (U.S. Department of Health, Education, and Welfare), 1970, *Radiological Health Handbook*, revised edition, January 1970.

6. CONFIRMING THE COMPLETENESS OF THE RESULTS

This section compares the contaminant inventory against estimates given in previous reports and in existing databases, to the extent that such comparisons are possible and meaningful. In some cases, adjustments were necessary to compare values on the same basis. The inventory is also compared against the list of contaminants detected in environmental monitoring conducted at the RWMC. The results of all these comparisons help to confirm the credibility and substantial completeness of the inventory compiled in this task.

Although estimates of waste volume are included in CIDRA, no similar comparisons have been performed to confirm the accuracy of the volume estimates. The BRA will not use the volume estimates from CIDRA, so no special confirmation was considered necessary.

6.1 Comparison of Inventory with Estimates Given in Earlier Reports

Many earlier reports (see the references cited in Sections 2 and 3, for example) provide useful information on the inventories of contaminants buried in the SDA. The earlier reports were examined as part of the data-gathering for the HDT. However, the inventories in the earlier reports either (a) contain estimates for only a portion of the total inventory (e.g., only one disposal unit), (b) provide mostly or solely qualitative information, (c) deal with a somewhat different time period, or (d) were developed for a different purpose and made different assumptions to deal with the lack of definitive data in the original records. Therefore, only limited comparisons were possible between the total inventory developed in the HDT and the inventories in previous reports. Nevertheless, even the limited comparisons are useful to help confirm the credibility and substantial completeness of the current results.

6.1.1 Nonradiological Contaminants

Several reports provide estimates of the nonradiological contaminants disposed of in the SDA. Some of the reports provide estimates for waste disposed of in essentially the entire SDA; others concentrate on one particular disposal unit, such as Pad A, Pit 9, or the Acid Pit.

The CIDRA estimates are intended to be best estimates for waste buried in the entire SDA from 1952 through 1983. If contaminants were known to be present but no definitive information on the quantities was available, the best estimate was listed as unknown. Separately, attempts were made to provide an upper bound or inexact estimate for these unknown quantities, using various assumptions. The evaluation of these unknown quantities is provided in Section 4 and Appendix D.

The CIDRA inventory of nonradiological contaminants was compared against the inventory information listed in seven documents. Three of these documents contain information on waste that was disposed of in the entire SDA, two documents apply only to waste disposed of in Pit 9, one document applies only to waste placed on Pad A, and one document applies only to waste disposed of in the Acid Pit.

Cerven (1987) provides a compilation of nonradiological contaminants in the SDA. The data are based on RWMIS and on technical estimates and interviews involving personnel familiar with the waste generators or with RWMC operations. The compilation included disposal through 1987, rather than the 1983 cutoff used in this document, but it excluded some sludges, resins, and waste in the Acid Pit.

- The draft *Remedial Investigation/Feasibility Study Work Plan for the Subsurface Disposal Area Radioactive Waste Management Complex at the INEL* (EG&G Idaho 1989) provides estimates of the nonradiological contaminants disposed of in the SDA. It includes data from Cerven (1987), but it provides a more detailed analysis of the information. It also includes data from Garcia and Knight (1989a) and other documents.

Garcia and Knight (1989a) was used for SDA information because it was a source document for data on the estimated amounts of lead and mercury disposed of in the SDA. The majority of the document addresses estimates of Pit 9 contents. To prevent confusion on the applicability of the data, no Pit 9 data from Garcia and Knight were used in the present comparisons. Instead, Liekhus (1992) and Figueroa et al. (1992) were used for the Pit 9 information.

Halford et al. (1993) provides information for comparison of the nonradiological contaminants on Pad A. The report provides estimated chemical masses for the inorganic constituents in the RFP evaporator salts on Pad A based on a private communication. The report also provides analyses of one RFP salt drum retrieved from Pad A in January 1990, resuspended nitrate salt dust from the RFP drum loading area that was sampled in 1984, a 1978 sample of 36% salt solution from the RFP feed pond, and calculated concentrations from the shipping records covering 1972 through 1976.

Liekhus (1992) and Figueroa et al. (1992) provide detailed analysis of the nonradiological contaminants estimated to have been disposed of in Pit 9. The Pit 9 inventory has been the subject of considerable study as part of the CERCLA interim action activities of the Pit 9 project. In addition, Pit 9 is expected to contain a substantial fraction of the inventory of certain nonradiological contaminants in the entire SDA during the time period of interest. Therefore, comparisons against the Pit 9 inventory are useful.

The majority of Pit 9 waste came from the RFP. The Pit 9 inventory is based mainly on RWMIS, shipping records, and numerous assumptions and calculations in Liekhus (1992). Some of the Liekhus results were intentionally conservative, worst-case estimates based on calculations in the absence of definitive information in the waste records. The Liekhus estimates were intended to provide upper-limit inventories for use in the safety analysis report and the hazard classification of the Pit 9 project. Thus, because of the worst-case assumptions and the single disposal unit, the Pit 9 results are not strictly comparable with those in CIDRA, which include almost the entire SDA.

Jorgensen (1992) provides results and assessments of the characterization studies performed on the Acid Pit and a compilation of the disposal records for the waste disposed of in that unit. The compilation provides volumes and compositions of waste. It sometimes provides concentrations of the contaminants. For the comparisons presented in this report, some assumptions were necessary and calculations were performed on the Jorgensen results to convert them to estimated grams of the nonradiological contaminants disposed of in the Acid Pit.

Tables 6-1 and 6-2 compare the nonradiological organic (Table 6-1) and inorganic (Table 6-2) contaminants estimated in CIDRA and in the inexact estimates of the unknown quantities (from Section 4 and Appendix D) against estimates in the seven other reports discussed above.

An additional report, on organic contamination in the vadose zone underlying the SDA (Duncan et al. 1993), was also reviewed but is not included in Table 6-1. The inventory data in the report are the same quantities of organic compounds given in the Cerven (1987) and EG&G Idaho (1989) reports, which are included in Table 6-1.

The first conclusion from the comparisons is that the information in CIDRA and in the unknown quantities list includes many more contaminants than are listed in the seven other reports. This might be expected for the Pit 9 and Acid Pit data, because those reports address only one disposal unit. The combined CIDRA and unknown quantity list is longer than the contaminant list for the other SDA reports because of the increased efforts to obtain the information for this report.

The following paragraphs compare the combined values from CIDRA and the unknown quantities against the values in the other reports. Only the highlights of the comparisons are discussed, with most of the emphasis on explaining any entries for which the other reports listed larger quantities than those estimated in this report.

Ethylene glycol. The Cerven (1987) report furnished information on seven drums of ethylene glycol buried in a trench at the SDA between 1954 and 1970. The present search did not identify ethylene glycol in any of the waste streams.

Benzene and benzine. The Cerven (1987) report furnished some information on 0.1 m^3 of waste containing benzene. A review of the RWMIS potential hazardous materials listing did not show any benzene, but it did show 0.085 m^3 of benzine. It is assumed here that Cerven took this to be a typographic error and listed the material as benzene, and the quantity was rounded to 0.1 m^3. Therefore, the quantity of benzene in the Cerven report is listed in Table 6-1 as benzine. Benzene is estimated in this report as an unknown quantity at a mass of 1.2E+05 g. No other reports estimated any benzene in the SDA.

The quantity of benzine came from two RWMIS entries. One of these entries had a weight with it, but the other one did not. A density was calculated based on the one weight and volume, and that density was used to calculate the other weight. The derived weight (1.1E+04 g) is higher than the amount reported in CIDRA. The total weight shown in RWMIS is not from the benzine liquid. Therefore, it is expected that the CIDRA number is actually very close to the real quantity of benzine that is present in the RWMIS entries.

Carbon tetrachloride. The CIDRA number is slightly lower than the 1.5E+08 g that is shown in two other SDA reports. All of the numbers were derived from the Kudera (1987) report and would normally be the same. However, to provide the CIDRA estimate for the VOCs, the calculated quantities were assumed to be the upper bounds and the CIDRA best estimate was calculated to be three-fourths of the upper bound. This was done to provide some allowance for evaporation during the generation of the waste, storage of the waste before closure of the drum, and some possible venting of the drum before the actual covering with soil at the disposal site.

Table 6-1. Comparisons of nonradiological organic contaminant inventories in the CIDRA database and in the unknown quantities[a] against inventories in other reports.

	Subsurface Disposal Area				Pit 9		Acid Pit
Constituent	CIDRA best estimate (g)	Unknown quantities[a] (g)	Cerven (1987) (g)	EG&G Idaho (1989) (g)	Liekhus (1992) (g)	Figueroa et al. (1992) (g)	Jorgensen (1992) (g)
Organic Acids							
Ascorbic acid	—	7.1E+07	—	—	—	—	—
EDTA[b]	—	7.1E+07	—	—	—	2.3E+06	—
Alcohols							
Methanol	2.2E+05	2.8E+05	—	—	—	—	—
Ethanol	2.2E+04	7.1E+07	—	—	—	—	5.1E+00
Butanol	9.9E+04	—	—	—	—	—	—
Ethylene glycol	—	—	1.5E+06	—	—	—	—
Other Organics							
Acetone	1.1E+05	—	—	—	—	—	2.2E+00
Anthracene	2.0E+02	—	—	—	—	—	—
Benzene	—	1.2E+05	—	—	—	—	—
1,4-bis(5-phenyloxasol-2yl)benzene	—	2.0E+05	—	—	—	—	—
Benzine[c]	4.0E+03	—	1.1E+04	—	—	—	—
Butanone[d]	3.2E+04	—	—	—	—	—	—
Carbon tetrachloride	1.2E+08	2.0E+05	1.5E+08	1.5E+08	3.3E+07	5.2E+07	3.2E+01
Chloroform	3.7E+01	1.0E+07	—	—	—	—	—
Dibutylethylcarbutol	—	5.4E+06	—	—	—	—	—
Diisopropylfluorophosphate	—	<< E+05	—	—	—	—	—
Diphenyl	—	1.8E+08	—	—	—	—	—
Ether	—	Unknown	7.2E+05	—	—	—	—
Formaldehyde	1.4E+05	—	—	—	—	—	—
Freon[e]	9.1E+06	—	—	—	—	—	—
3-methyl-cholanthrene	—	1.0E+05	—	—	—	—	—

Table 6-1. (continued).

Constituent	Subsurface Disposal Area				Pit 9		Acid Pit
	CIDRA best estimate (g)	Unknown quantities[a] (g)	Cerven (1987) (g)	EG&G Idaho (1989) (g)	Liekhus (1992) (g)	Figueroa et al. (1992) (g)	Jorgensen (1992) (g)
Methylene chloride	1.4E+07	—	—	—	—	—	—
Methyl isobutyl ketone	8.9E+06	—	—	—	—	—	—
Nitrobenzene	—	Trace	—	—	—	—	—
Nitrocellulose	—	6.8E+06	—	—	—	—	—
Polychlorinated biphenyls[f]	—	2.4E+03	—	—	—	—	—
Terphenyl	4.5E+05	5.9E+08	—	—	—	—	—
Tetrachloroethylene	2.7E+07	—	—	4.1E+07	—	1.9E+07	—
Toluene	1.9E+05	2.0E+05	—	—	—	—	—
Tributylphosphate	1.0E+06	—	—	—	—	—	8.5E+01
Trichloroethane[g]	1.1E+08	—	—	2.5E+07	1.5E+07	1.5E+07	—
Trichloroethylene	1.0E+08	—	—	3.7E+07	—	1.7E+07	—
Trimethylpropane-triester	1.2E+06	—	—	—	—	—	—
Xylene	8.5E+05	—	—	—	—	—	—

a. The values listed for the unknown quantities are inexact estimates and, therefore, of lesser reliability than the values listed under CIDRA. They are not included in CIDRA.

b. EDTA or Versenes — ethylenediaminetetraacetic acid.

c. Benzine — a mixture of hydrocarbons, used as a motor fuel and in dry cleaning (*not* benzene).

d. Butanone — 2-butanone.

e. Freon — 1,1,2-trichloro-1,2,2-trifluoroethane.

f. Polychlorinated biphenyls — PCBs.

g. Trichloroethane — 1,1,1-trichloroethane.

Table 6-2. Comparisons of nonradiological inorganic contaminant inventories in the CIDRA database and in the unknown quantities[a] against inventories in other reports.

	Subsurface Disposal Area					Pad A	Pit 9		Acid Pit
Constituent	CIDRA best estimate (g)	Unknown quantities[a] (g)	Cerven (1987) (g)	EG&G Idaho (1989) (g)	Garcia and Knight (1989a) (g)	Halford (1993) (g)	Liekhus (1992) (g)	Figueroa et al. (1992) (g)	Jorgensen (1992) (g)
Inorganic Acids	—	—	3.9E+07	3.9E+07	—	—	—	—	—
Aqua regia	3.1E+01	—	—	—	—	—	—	—	—
Hydrochloric acid	—	—	—	—	—	—	—	—	2.5E+04
Hydrofluoric acid	7.6E+06	2.2E+06	—	—	—	—	—	—	1.5E+04
Nitric acid	5.0E+07	2.3E+06	—	—	—	—	—	—	2.2E+07
Sulfuric acid	1.2E+05	—	—	—	—	—	—	—	1.4E+04
Other Inorganics									
Aluminum nitrate	1.9E+08	—	—	—	—	—	—	—	1.8E+08
Ammonia	7.8E+05	—	—	—	—	—	—	—	1.6E+05
Antimony	4.5E+02	—	—	—	—	—	—	—	—
Asbestos	1.2E+06	2.3E+06	2.6E+07	2.6E+07	—	—	4.0E+05	4.0E+05	—
Beryllium[b]	1.5E+07	8.0E+06	—	—	—	—	2.0E+04	2.0E+04	—
Cadmium	1.6E+06	—	—	—	—	—	—	—	—
Calcium silicate	—	—	—	—	—	—	4.4E+07	4.4E+07	—
Caustic[c]	1.5E+02	—	—	1.0E+06	—	—	—	—	3.7E+04
Cerium chloride	5.1E+05	—	—	—	—	—	—	—	—
Chromium	1.0E+03	—	—	—	—	—	—	—	—
Copper	—	4.5E+04	—	—	—	—	—	—	—
Copper nitrate	3.3E+02	—	—	—	—	—	—	—	—
Cyanide[d]	9.4E+02	2.9E+03	—	—	—	—	—	—	2.0E+02
Hydrazine	1.8E+03	—	—	—	—	—	—	—	2.2E+03
Lead	5.8E+08	2.0E+07	1.9E+09	2.3E+08	3.6E+08	—	3.0E+06	3.0E+06	—
Lithium	—	—	—	—	—	—	1.0E+04	1.0E+04	—
Lithium hydride	—	Unknown	—	—	—	—	—	—	—
Lithium oxide	—	Trace	—	—	—	—	—	—	—
Magnesium	9.0E+06	2.8E+05	—	—	—	—	—	—	—
Magnesium fluoride	1.4E+05	—	—	—	—	—	—	—	—
Magnesium oxide	—	2.8E+08	—	—	—	—	—	—	—

Table 6-2. (continued).

Constituent	Subsurface Disposal Area					Pad A	Pit 9		Acid Pit
	CIDRA best estimate (g)	Unknown quantities[a] (g)	Cerven (1987) (g)	EG&G Idaho (1989) (g)	Garcia and Knight (1989a) (g)	Halford (1993) (g)	Liekhus (1992) (g)	Figueroa et al. (1992) (g)	Jorgensen (1992) (g)
Manganese	—	1.0E+04	—	—	—	—	—	—	—
Mercuric nitrate	8.1E+05	—	—	—	—	—	—	—	5.6E+05
Mercury	—	1.2E+06	—	—	1.1E+08	—	1.0E+05	1.0E+05	—
Nickel	2.2E+03	—	—	—	—	—	—	—	—
Potassium chloride	1.3E+08	—	—	—	—	5.1E+07	—	—	—
Potassium dichromate	1.7E+06	—	—	—	—	—	—	—	—
Potassium hydroxide	—	—	—	—	—	5.1E+07	—	—	—
Potassium nitrate	3.2E+09	—	—	—	—	1.4E+09	—	5.8E+07	—
Potassium phosphate	4.0E+07	—	—	—	—	—	—	—	—
Potassium sulfate	1.3E+08	—	—	—	—	5.1E+07	—	—	—
Silver	5.9E+03	—	—	—	—	—	—	—	—
Sodium	6.8E+04	1.0E+02	—	—	—	—	—	—	—
Sodium chloride	2.6E+08	—	—	—	—	1.0E+08	—	—	—
Sodium dichromate	3.1E+06	—	—	—	—	—	—	—	—
Sodium hydroxide	—	—	—	—	—	1.0E+08	—	—	—
Sodium nitrate	6.3E+09	4.5E+05	—	—	—	2.7E+09	—	1.2E+08	1.7E+06
Sodium phosphate	8.0E+07	—	—	—	—	—	—	—	—
Sodium sulfate	2.6E+08	—	—	—	—	1.0E+08	—	—	—
Sodium-potassium	1.7E+06	Small	—	—	—	—	—	—	—
Uranyl nitrate	2.2E+05	—	—	—	—	—	—	—	—
Zirconium	1.9E+07	—	2.0E+08	5.8E+08	—	—	1.5E+07	1.5E+07	—
Zirconium alloys	5.9E+06	—	—	—	—	—	—	—	—

a. The values listed for the unknown quantities are inexact estimates and, therefore, of lesser reliability than the values listed under CIDRA. They are not included in CIDRA.

b. Beryllium—beryllium as the metal or the oxide.

c. Caustic—sodium hydroxide.

d. Cyanide—sodium cyanide.

Ether. The RWMIS potential hazardous materials listing in the Cerven (1987) report contains a content code that was named, "Ether, Organics, Diphenyl." The total volume of the entries for this content code was 12.6 m^3, with a total weight of 2.9E+06 g. If one-fourth of the weight is due to ether, then the quantity would be 7.2E+05 g. The present search did not provide any quantitative values for the ether that was identified. It is possible that the entry given by Cerven was for the diphenyl listed above it in Table 6-1.

Tetrachloroethylene, trichloroethane, and trichloroethylene. The RI/FS Work Plan for the SDA (EG&G Idaho 1989) used the volume of "other organics" from the Kudera (1987) report and assumed that 20% of that volume was trichloroethane, one-third of the remaining volume was tetrachloroethylene, and another third of that volume was trichloroethylene.

The best estimate for CIDRA was made by using the same Kudera report and by assuming that there was no used oil present and the ratios of 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene in this "other organic" was the same as their ratios in the 1974 Harmful Materials Inventory at the RFP (ChemRisk 1992). Because this method only provided an estimate of the relative amounts of each of the VOCs in the volume of "other organics," the percentages of each were rounded to 45%, 45%, and 10% for making the best estimates.

Total inorganic acids. The data from EG&G Idaho (1989) actually come from the estimates of hazardous constituents in the SDA in the Cerven (1987) report. The data do not list any concentrations of particular acids; the entry is simply for 10,200 gal of acids. The total mass value was calculated assuming a density of 1 g/cm^3 of liquid. This number is a little higher than the total mass calculated for acids in the Acid Pit and a little lower than the total mass for all acids reported in CIDRA.

Asbestos. These data in EG&G Idaho (1989) also come from the Cerven (1987) report. The data state that 100 m^3 of asbestos was buried in the SDA. This was converted to grams by assuming a density of 16 lb/ft^3. It is probably a high number because it also assumes that the waste containers are completely full of asbestos. However, the CIDRA best estimate is probably low, but no data have been identified that justify raising the estimate.

Beryllium. The beryllium estimates in CIDRA and the unknown quantities are much higher than the estimates for waste buried in Pit 9. This is to be expected because Pit 9 is only one disposal unit. However, the Cerven (1987) and EG&G Idaho (1989) reports do not mention any beryllium or beryllium oxide. The RWMIS potential hazardous materials listing attached to the Cerven report does list beryllium, but it is not highlighted in the Cerven table of hazardous material constituents buried in the SDA. The total beryllium, excluding any neutron sources, in the RWMIS listings is 46 m^3. At a density of 1.85 g/cc, this calculates to 8.5E+07 g. If only one-tenth of the total volume were beryllium, this would be an estimate of 8.5E+06 g of beryllium. This estimate is similar to the best estimate provided in CIDRA. Differentiation between beryllium and beryllium oxide in the waste streams is not always possible. The unknown quantity estimate is a combination of beryllium metal and beryllium oxide estimates.

Calcium silicate. Calcium silicate was used at the RFP as an absorbent for organic liquids to convert them into sludge. The mass of this compound was not calculated for CIDRA because (a) the

compound was not identified on any regulatory list of hazardous substances and (b) no quantitative risk assessment can be performed because of the lack of EPA-approved toxicity data.

Caustic (sodium hydroxide). The quantities given in EG&G Idaho (1989) and for the Acid Pit are much higher than the quantity listed in CIDRA. EG&G Idaho (1989) lists caustic compounds as 26 m^3, which was converted here to 6,900 gal. It was assumed that this 6,900 gal was 1M (40 g/L) sodium hydroxide. The 26 m^3 came from the Cerven (1987) report, which describes the caustic compounds as sodium hydroxide in absorbent. This indicates that it was probably not 6,900 gal of 1M sodium hydroxide. However, it also means that providing a comprehensive and reliable estimate of the quantity of caustic (NaOH) disposed of in the SDA may not be possible.

The Acid Pit quantity was estimated from actual volumes disposed of; however, no concentrations were given. The estimate of the total grams in the Acid Pit was made assuming that the liquid was 2M (80 g/L) sodium hydroxide. It is difficult to provide a good estimate of caustic disposed of because it can react with acids or other compounds to form a third compound, such as sodium nitrate.

Lead. The quantity of lead listed in RWMIS as being buried in the SDA is 170 m^3. If the normal density of lead is used (11,300 kg/m^3), this calculates to the mass of 1.9E+09 g given in Cerven (1987). Garcia and Knight (1989a) used some RWMIS data and other assumptions to calculate a density of 2,134 kg/m^3 for the lead waste stream. Thus, the Garcia and Knight report shows a quantity of 3.6E+08 g of lead. Garcia and Knight proposed using the 1.9E+09 g as an upper limit and the 3.6E+08 g as a lower limit. The quantity in CIDRA (5.8E+08 g) is between the two suggested limits of Garcia and Knight.

Lithium and lithium oxide. The Liekhus (1992) Pit 9 report assumed that 16 pints of mercury was disposed of in the Acid Pit and that the lithium in lithium batteries is one-tenth of the amount of mercury. Actually, the lithium metal in the batteries is converted to an oxide as the batteries discharge; therefore, the lithium batteries disposed of would be expected to contain lithium oxide instead of lithium. Because there is no information on how many lithium batteries were disposed of at the SDA, the amount of lithium oxide could be estimated in CIDRA only as a trace.

Mercury and mercuric nitrate. The Liekhus (1992) Pit 9 report assumed that 16 pints of mercury was disposed of in the Acid Pit. The Cerven (1987) report found 8.5 m^3 of waste containing mercury in the RWMIS potential hazardous materials listings. The Garcia and Knight (1989a) report calculated (using a density of 13,500 kg/m^3) that a volume of 8.5 m^3 of mercury would equal 1.1E+08 g. This assumed that the entire volume of the waste was pure mercury. CIDRA listed the metallic mercury as unknown, and the estimate of this unknown is 1.2E+06 g. CIDRA also identified 4.7E+05 g of mercury that is present as mercuric nitrate monohydrate (8.1E+05 g). By examining the shipping records, the HDT study determined that one shipment of 120 ft^3 (3.4 m^3) of mercury listed in RWMIS actually consisted of soil contaminated with mercury (see Appendix D for details).

It appears, therefore, that the 1.1E+08 g of mercury (Garcia and Knight 1989a) is not a realistic estimate for the quantity buried in the SDA. It appears that the 1.2E+06 g quantity of mercury, which was calculated as an unknown quantity, is the best estimate that can be made at this time.

Sodium and potassium dichromates. An analysis of one drum of nitrate salts from Pad A (Halford et al. 1993) showed chromium at a concentration of 400 mg/kg. In the presence of high concentrations of nitrates at a pH of 9 to 10, it is expected that stable dichromates of sodium and potassium would be present. Because chromium can be a hazardous constituent of waste, the assumed quantities of these compounds in the nitrate salts was calculated.

Sodium and potassium hydroxides. These compounds were reported in the Pad A Halford et al. (1993) report. However, the same report presented a chemical analysis of a sample from one drum that showed a pH of 9 to 10. This pH indicates that only a small amount of hydroxides would be present in the waste. The analysis showed that, in addition to the nitrates, there were chlorides, sulfates, phosphates, fluorides, and nitrites. Therefore, the best estimate of the composition of these nitrate salts includes 4% chlorides, 4% sulfates, and 2% phosphates. No hydroxides were estimated in the nitrate salts on Pad A.

Zirconium. The search of the RWMIS potential hazardous materials listing by Cerven (1987) identified 30 m^3 of zirconium chips disposed of in the SDA. If it was assumed that all of this waste is pure zirconium at a density of 6.5 g/cm^3, there would be 2.0E+08 g of zirconium buried in the SDA. It is not expected that the entire volume would be pure zirconium; therefore, this is expected to be a maximum quantity.

EG&G Idaho (1989) lists a maximum quantity of zirconium buried in the SDA as 5.8E+08 g and a minimum quantity of 3.6E+07 g. This information came from Garcia et al. (1989). The evaluation of the metal content of Pit 9 by Garcia et al. was made using information in RWMIS. It was then assumed in EG&G Idaho (1989) that the rest of the SDA would have the same metal composition as Pit 9. It was also assumed that the maximum weight percent metal would be 80% of the total weight of the waste, and the minimum weight percent of the metal would be 5% of the total weight of the waste. The zirconium percentage was assumed to be 2.6% of the weight of the metal, as calculated for Pit 9.

The CIDRA best estimate for zirconium (1.9E+07 g) plus 5.9E+06 g of zirconium alloys is lower than the minimum quantity given in EG&G Idaho (1989) and, therefore, may be low. However, many assumptions were made in development of the zirconium estimates in the other reports, and the assumptions could prove to be unrealistic.

In summary, CIDRA provides estimates of many more nonradiological contaminants than does any other study performed on the SDA. Except for the estimates of asbestos, caustic, and zirconium, it appears that the CIDRA best estimates plus the unknown quantities fall in an expected range. For the asbestos, caustic, and zirconium quantities, consideration should be given to the objectives for use of the data. In some cases, further evaluation may be necessary.

6.1.2 Radiological Contaminants

The CIDRA data were compared against several other reports containing radionuclide inventories (see Table 6-3). For valid comparisons of the CIDRA data with radionuclide inventories in other reports, several aspects of the inventories must match. These aspects include the time period under consideration, the sources of the waste, the type of waste considered, and in which part of the

Table 6-3. Comparison of radiological inventories in the CIDRA database against those in other reports.

Radionuclide	CIDRA best estimate[a] 1952–1983 (Ci)	Litteer et al. (1993) 1952–1983 (Ci)	Figueroa et al. (1992) Pit 9 (Ci)	EG&G Idaho (1989) TRU waste only 1954–1970 (Ci)	Garcia and Knight (1989b) Pit 9 (Ci)
Co-60	2.8E+06	—	3.1E-01	9.9E+04	—
Sr-90	4.5E+05	—	4.2E+00	1.0E+03	—
Cs-137	7.0E+05	—	4.5E+00	1.0E+03	—
Ni-59	5.1E+03	—	—	1.5E+03	—
MAP	—	—	—	6.0E+03	—
MFP	—	—	—	5.0E+02	—
Unidentified beta-gamma	—	—	—	5.5E+03	—
Pu-238	2.5E+03	—	3.1E+01	5.7E+02	5.6E+02
Pu-239	6.6E+04	—	1.2E+03	2.1E+04	2.1E+04
Pu-240	1.5E+04	—	2.7E+02	4.9E+03	4.9E+03
Pu-241	4.0E+05	—	9.4E+03	1.8E+05	1.6E+05
Pu-242	9.9E-01	—	1.3E-02	2.0E-01	2.3E-01
Am-241	1.5E+05	—	2.1E+03	4.8E+04	5.1E+04
U-233	1.1E+00	—	—	5.0E-01	—
U-234	6.4E+01	—	—	—	6.1E+00
U-235	5.1E+00	—	—	3.0E-01	2.8E-01
U-238	1.1E+02	—	—	6.8E+01	6.8E+01
Total	1.2E+07	9.7E+06	1.3E+04	3.7E+05	2.4E+05

a. For CIDRA, the only radionuclides listed are those that were listed in the other reports. The CIDRA total, however, represents all of the radionuclides in the CIDRA inventory.

SDA the waste was buried. This study examined all waste buried at the SDA from all generators from 1952 through 1983. Figueroa et al. (1992) shows dramatically lower numbers for all radionuclides because the data in that report represent shipments primarily from only 1 year (1968), mostly from one source (the RFP), going to one disposal unit (Pit 9). Thus, the radioactivity inventory in Figueroa et al. (1992) can legitimately be orders of magnitude less than that in CIDRA.

The summary-to-date data in Litteer et al. (1993) include all waste buried in the RWMC through 1983 from all generators. The summary in that report offers only a total over all radionuclides. That total is approximately 2 million Ci less than the CIDRA total. This is to be expected because the HDT identified substantial radioactivity not included in RWMIS.

EG&G Idaho (1989) is like Figueroa et al. (1992) in that it takes a limited look at waste buried at the SDA because it was concerned with TRU waste. It refers to beta/gamma-emitting waste in the context of its having been mixed with TRU waste. The report offers inventories of some radionuclides that are close to the CIDRA values in some cases. For instance, the CIDRA value for Pu-239 is only about three times that of reported EG&G Idaho (1989). Throughout EG&G Idaho (1989), however, the values are smaller than those in CIDRA, as would be expected for a partial inventory.

The data in Garcia and Knight (1989b) likewise show lower activities than does CIDRA for all reported radionuclides, mostly because Garcia and Knight considered only data for waste that was buried in Pit 9 and originated at the RFP. In fact, the numbers in Garcia and Knight (1989b) are almost identical to those in EG&G Idaho (1989). This is not surprising because both of these reports take data from a single source. That source was a letter (Lee 1971) that transmitted data on RFP solid waste shipped to the INEL from 1954 through 1970.

Plansky and Hoiland (1992) contains data nearly identical to those found in RWMIS. A detailed comparison was not carried out because a comparison against RWMIS is made in Sections 6.2.3 and 6.2.4. The principal contribution made by Plansky and Hoiland was to provide a radionuclide distribution for the large activity listed previously in RWMIS under generic terms.

A comparison of CIDRA results for the radionuclides in waste from the RFP with the data recorded in these other reports (Table 6-4) shows a closer correspondence, reflecting the emphasis of these other reports exclusively on buried TRU waste and the fact that nearly all TRU waste at the SDA came from the RFP. CIDRA values are about two to three times those in EG&G Idaho (1989) for the more significant radionuclides (Pu-238, Pu-239, Pu-240, Pu-241, and Am-241). The CIDRA total is 2.5 times the EG&G Idaho (1989) total. These results are to be expected, given the increase in estimated activity of plutonium and americium brought about by this study and the fact that the other reports address only part of the waste. The Co-60, Cs-137, H-3, and Ra-226 listed under the CIDRA best estimate reflect a waste stream consisting of radiation sources. The stream is not identified in the shipping records and, therefore, was not identified in the other studies.

The data for RFP waste were also compared against data from the RFP that were discussed in Kudera (1994). That document compiled information from a 1964 study performed at the RFP. The RFP study estimated the amounts of plutonium discarded in various waste streams from 1954 through June 30, 1963. Many of the estimates were based on limited sampling and laboratory analyses. The

Table 6-4. Comparison of the CIDRA database radionuclide inventory for Rocky Flats Plant waste only against that in other reports.

Radionuclide	CIDRA best estimate 1952–1983 (Ci)	Litteer et al. (1993) 1952–1983 (Ci)	Figueroa et al. (1992) Pit 9 (Ci)	EG&G Idaho (1989) TRU waste only 1954–1970 (Ci)	Garcia and Knight (1989b) Pit 9 (Ci)
Am-241	1.5E+05	—	2.1E+03	4.8E+04	5.1E+04
Pu-238	1.9E+03	—	3.1E+01	5.7E+02	5.6E+02
Pu-239	6.5E+04	—	1.2E+03	2.1E+04	2.1E+04
Pu-240	1.4E+04	—	2.7E+02	4.9E+03	4.9E+03
Pu-241	3.9E+05	—	9.4E+03	1.8E+05	1.6E+05
Pu-242	8.8E-01	—	1.3E-02	2.0E-01	2.3E-01
U-232	1.2E-02	—	—	—	—
U-233	5.4E-01	—	—	5.0E-01	—
U-234	3.8E+01	—	—	—	—
U-235	1.9E+00	—	—	3.0E-01	2.8E-01
U-236	1.0E+00	—	—	—	—
U-238	8.0E+01	—	—	6.8E+01	6.8E+01
Co-60	1.7E+02	—	—	—	—
Cs-137	2.1E+02	—	—	—	—
H-3	3.6E-01	—	—	—	—
Ra-226	1.9E-01	—	—	—	—
Total	6.2E+05	2.5E+05	1.3E+04	2.5E+05	2.4E+05

estimated total of plutonium was 456.9 kg plus an unknown amount in boxed waste, which typically includes processing equipment, duct work, and piping. This value was compared against the quantity estimated for the HDT study in Appendix C, which used a completely different calculational approach. Based on the plutonium quantities for 1952 through 1962 plus one-half of the 1963 quantity, the Appendix C estimate is 431.7 kg. Thus, for the years indicated, the present estimate is within about 6% of an independent estimate, with the exception of the impact of the unknown quantity of plutonium in the boxed waste.

Thus, the limited comparisons that were possible against other reports containing radiological inventories for the SDA indicate that the inventory in CIDRA is substantially complete.

6.2 Comparison of Inventory with Inventories in Existing Databases

6.2.1 Introduction

This section compares the contaminant inventory developed in the HDT with corresponding inventories in existing databases. One objective was to confirm the substantial completeness and accuracy of the data collection for this task. A second objective was to identify and explain any major differences in inventory values between the databases and justify the new values that will be used in the BRA.

Only one database was identified against which to compare the complete contaminant inventory. That database is RWMIS, with the associated Qualifier Flag/Additional Contents database (see Section 2.3). Because RWMIS contains little information on nonradiological contaminants in the waste and no estimates of uncertainties, the comparisons involved only best estimates of radiological contaminants.

Because of the thousands of data involved in the radiological inventory, the comparisons reported here were made for general checking. The comparisons were not intended to be an exact accounting (which would not be useful because of the uncertainties in the data).

6.2.2 The Effect of RWMIS Data Groupings on the Comparisons

The nature of RWMIS affects the approach used here in the comparisons. RWMIS can provide inventories of the radionuclides in the waste based on two groupings of data. One RWMIS grouping involves rollups of the data that were provided on individual shipping records. RWMIS rollups of this type are referred to here as the RWMIS shipping record rollups. The advantage of these rollups is that they are radionuclide-specific. The disadvantage is that the rollups are incomplete for the period 1952 through 1970 because of missing shipping records.

The second RWMIS grouping involves the data summaries that have been prepared annually on the radioactivity in waste disposed of at the SDA. RWMIS data of this type are referred to here as RWMIS annual summaries. These data differ from the RWMIS shipping record rollups because they include estimates made in 1971 of the annual radioactivity in waste shipped to the SDA by each generator in all preceding years. (The 1971 estimates of the waste from 1952 through 1970 were made by waste management professionals in the form of an annual summary table, which was entered into RWMIS as a baseline. No documentation could be located on the basis for the 1971 estimates.) The advantage of these data is that they are substantially complete at the level of annual totals from each generator. The disadvantage of the data is that they do not include radionuclide distributions for all of the waste.

To incorporate this situation in the comparisons of CIDRA and RWMIS, two comparisons were made. One compares CIDRA data against the RWMIS shipping record rollups at the level of

individual radionuclide totals over all generators. The other compares CIDRA data against the RWMIS annual summary data at the level of total radioactivity from each major generator.

6.2.3 Comparisons at the Level of Individual Radionuclides, Summed Over All Generators

6.2.3.1 Approach. The RWMIS shipping record rollups were used for these comparisons against CIDRA. Figure 6-1 illustrates the approach. The strategy was to check for agreement first at the level of the total inventory of each radionuclide (over all waste generators). If, for a given radionuclide, the numbers were not reasonably close at that level, resolution was sought by comparisons at the level of the individual waste generators. Because CIDRA is organized by waste stream and RWMIS is organized by waste shipment, direct comparisons below the generator level were generally not feasible.

As the upper-right portion of Figure 6-1 shows, before the activities could be compared realistically, the RWMIS results had to be adjusted to replace the generic terms MAP, MFP, unidentified beta-gamma, and unidentified alpha with specific estimates by radionuclide. (Approximately 28% of the RWMIS radioactivity for 1952 through 1983 is listed in these generic terms.) The radionuclide distributions used in CIDRA for MAP, MFP, etc., vary by waste generator and sometimes even by waste stream for the same generator. *For purposes of this comparison only*, approximate breakdowns were developed as follows for each of the generic terms in RWMIS. For each generator, radionuclide distributions were identified that had been used in CIDRA, either for all waste streams or as a rough average (see Appendix E for the detailed distributions). These percentages were then multiplied by the RWMIS value, in curies, for each generic term for each generator. The resulting activities of each radionuclide were then added to the RWMIS values for the specific radionuclides. For example, the Co-60 activities deriving from the MAP value and from the unidentified beta-gamma value were added to the Co-60 activity that was listed separately in RWMIS. This process was performed for each affected radionuclide for each generator.

There is an additional complication. Section 5.4 noted that the radioactivity determinations for most waste containers were based on radiation surveys using G-M counters. The bias and random error of that method were discussed. A correction factor—multiplication by 0.5—was derived. CIDRA applies that correction factor to all best-estimate inventory entries for which uncertainties were not available, except as discussed in Section 5. Unfortunately, applying the correction factor makes it difficult to compare RWMIS and CIDRA as a completeness confirmation for CIDRA. For ease of comparison, the initial comparisons were made without the factor of 0.5 incorporated. The final comparisons reflect all of the inventory revisions made in CIDRA, as shown at the bottom of Figure 6-1.

6.2.3.2 Inventories as Listed in RWMIS and CIDRA. This section discusses how the inventory information was assembled for the comparisons. The columns of Table 6-5 indicate the results at various stages of the comparisons.

The first two columns of Table 6-5 list the total inventory for each radionuclide, as given in the RWMIS shipping record rollups. The radionuclides are listed in order of activity. The activities listed for the generic terms MFP, MAP, etc., are evident.

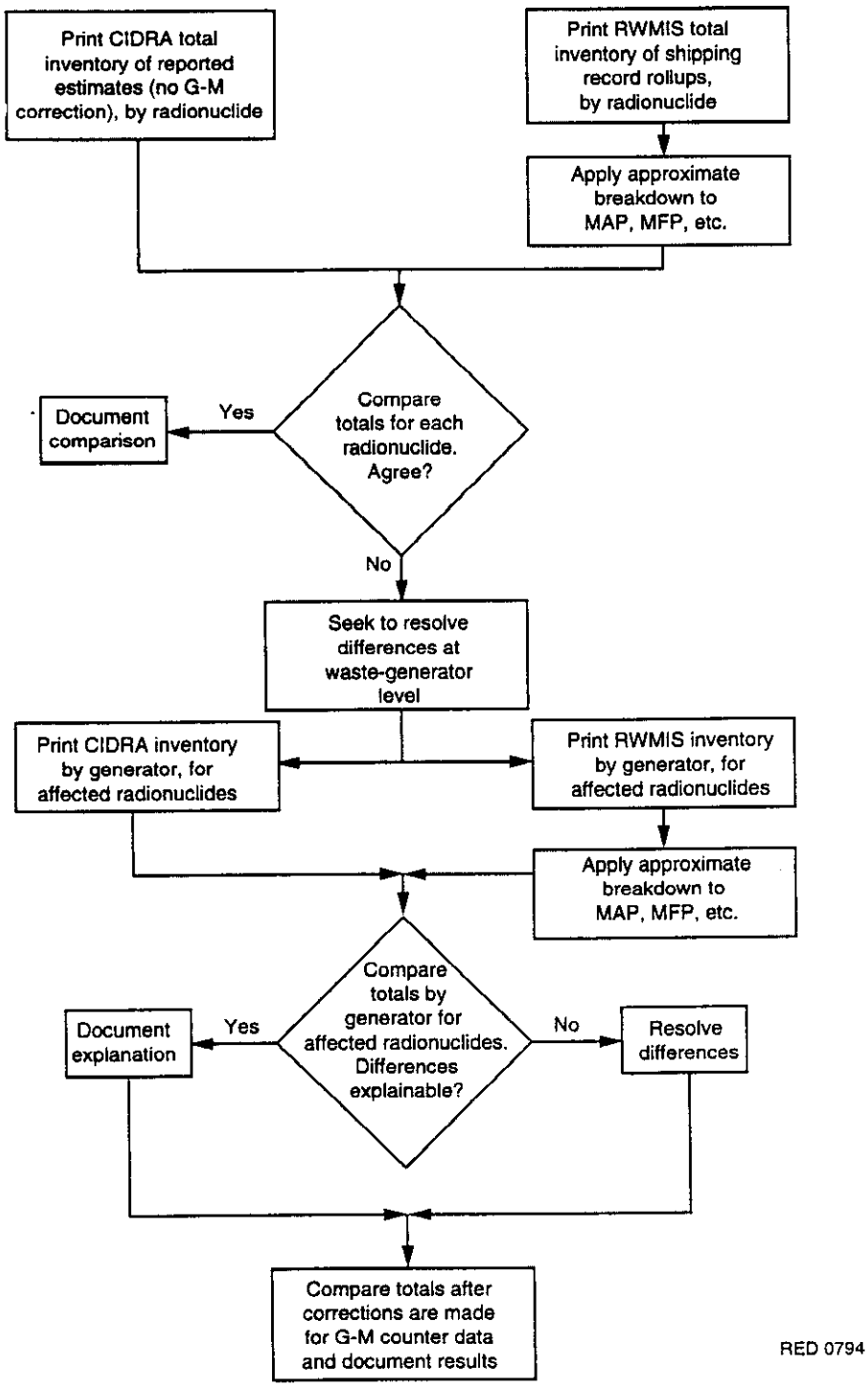

Figure 6-1. Approach for comparing the radionuclide inventory in the CIDRA database with that in the shipping record rollups of the RWMIS.

Table 6-5. Radionuclide inventories as given by RWMIS shipping record rollups and by CIDRA (with and without Geiger-Müller counter corrections): 1952—1983.

Radionuclide	RWMIS inventory (Ci)	RWMIS (with generic entries distributed) (Ci)	CIDRA reported estimates (no G-M corrections) (Ci)	CIDRA best estimate (with G-M corrections) (Ci)
Co-60	3.4E+06	4.1E+06	4.0E+06	2.8E+06
Cr-51	2.0E+06	2.0E+06	7.4E+05	7.3E+05
MFP	1.7E+06	0	0	0
MAP	8.2E+05	0	0	0
Co-58	6.6E+05	6.7E+05	1.6E+05	1.6E+05
Unidentified beta-gamma	5.3E+05	0	0	0
Mn-54	4.8E+05	4.9E+05	1.8E+05	1.8E+05
Zr-95	3.9E+05	4.1E+05	7.6E+04	7.6E+04
Fe-59	2.7E+05	2.7E+05	9.3E+04	9.1E+04
Fe-55	1.5E+05	3.3E+05	6.5E+06	3.8E+06
Sb-125	7.7E+04	1.2E+05	1.3E+05	1.3E+05
Ni-63	4.2E+04	4.2E+05	1.2E+06	7.4E+05
Zr-Nb-95	3.6E+04	0	0	0
Cs-137	3.3E+04	1.0E+06	1.2E+06	7.0E+05
Pu-241	3.3E+04	3.3E+04	4.1E+05	4.0E+05
Ce-141	2.8E+04	3.0E+04	1.5E+03	7.6E+02
Am-241	2.0E+04	2.0E+04	1.5E+05	1.5E+05
Sn-119m	2.0E+04	2.0E+04	2.7E+04	2.7E+04
Nb-95	1.6E+04	3.7E+04	2.7E+03	2.4E+03
Ce-144	1.2E+04	2.6E+05	1.7E+05	1.5E+05
Ru-103	9.6E+03	1.0E+04	7.2E+02	3.6E+02
H-3	9.5E+03	6.0E+04	1.3E+06	1.2E+06
Pr-144	8.8E+03	2.9E+04	4.2E+04	4.2E+04

Table 6-5. (continued).

Radionuclide	RWMIS inventory (Ci)	RWMIS (with generic entries distributed) (Ci)	CIDRA reported estimates (no G-M corrections) (Ci)	CIDRA best estimate (with G-M corrections) (Ci)
Ni-59	6.3E+03	9.1E+03	9.4E+03	5.1E+03
Sr-90	5.8E+03	3.4E+05	6.4E+05	4.5E+05
Pu-239	4.7E+03	4.7E+03	6.6E+04	6.6E+04
Y-90	3.3E+03	1.4E+04	1.9E+04	1.9E+04
Ru-106	2.6E+03	1.3E+04	6.8E+03	6.8E+03
Cs-134	1.8E+03	1.8E+03	2.6E+03	2.2E+03
Rh-106	1.8E+03	1.2E+04	6.8E+03	6.8E+03
Sr-Y-90	1.5E+03	0	0	0
Pu-240	1.5E+03	1.5E+03	1.5E+04	1.5E+04
U-235	7.1E+02	7.1E+02	5.2E+00	5.1E+00
Mn-56	5.8E+02	5.8E+02	2.7E+01	2.7E+01
Ce-Pr-144	5.6E+02	0	0	0
Pm-147	5.0E+02	5.0E+02	1.6E+02	8.1E+01
Eu-152	4.0E+02	4.0E+02	2.4E+02	2.4E+02
Zn-65	3.7E+02	3.7E+02	3.6E+02	3.6E+02
Eu-154	3.7E+02	3.7E+02	4.2E+03	3.0E+03
Pu-238	1.7E+02	1.7E+02	2.7E+03	2.5E+03
Eu-155	1.6E+02	3.1E+04	2.9E+04	1.5E+04
Ir-192	1.0E+02	1.0E+02	1.0E+02	5.4E+01
Be-10	9.0E+01	9.0E+01	4.3E+01	4.3E+01
La-140	8.7E+01	2.0E+03	1.5E+03	7.7E+02
Sc-46	8.7E+01	8.7E+01	5.3E+01	5.3E+01
Ru-Rh-106	8.4E+01	0	0	0

Table 6-5. (continued).

Radionuclide	RWMIS inventory (Ci)	RWMIS (with generic entries distributed) (Ci)	CIDRA reported estimates (no G-M corrections) (Ci)	CIDRA best estimate (with G-M corrections) (Ci)
Rb-86	7.7E+01	7.7E+01	1.4E+01	7.1E+00
Sb-124	7.6E+01	7.6E+01	1.8E+03	1.8E+03
Ba-140	6.7E+01	1.7E+03	1.3E+03	6.6E+02
Ra-226	3.0E+01	3.0E+01	6.9E+01	5.9E+01
Na-24	2.8E+01	2.8E+01	0	0
U-238	4.8E+01	4.8E+01	1.1E+02	1.1E+02
Po-210	1.8E+01	1.8E+01	8.0E+01	7.5E+01
I-131	1.4E+01	1.4E+01	1.5E+00	1.5E+00
Ba-La-140	1.1E+01	0	0	0
Ta-182	8.6E+00	8.6E+00	8.5E+00	8.5E+00
U-232	8.4E+00	8.4E+00	8.4E+00	8.4E+00
W-187	5.3E+00	5.3E+00	0	0
Co-57	4.8E+00	4.8E+00	4.8E+00	4.8E+00
Sr-89-90	3.9E+00	0	0	0
C-14	3.9E+00	8.5E+03	3.2E+04	1.6E+04
Sm-153	3.3E+00	3.3E+00	0	0
Ce-141-144	3.0E+00	0	0	0
Cd-109	2.9E+00	2.9E+00	4.1E-01	4.1E-01
Ag-110m	2.9E+00	2.9E+00	0	0
Unidentified alpha	2.8E+00	0	0	0
Nb-94	2.0E+00	2.0E+00	4.9E+01	4.9E+01
Sr-89	2.0E+00	1.2E+03	9.5E+02	4.7E+02
Hf-181	1.8E+00	1.8E+00	4.0E-01	3.6E-01

Table 6-5. (continued).

Radionuclide	RWMIS inventory (Ci)	RWMIS (with generic entries distributed) (Ci)	CIDRA reported estimates (no G-M corrections) (Ci)	CIDRA best estimate (with G-M corrections) (Ci)
Ag-110	1.7E+00	1.7E+00	1.7E+00	8.4E-01
Kr-85	1.4E+00	1.4E+00	1.3E+00	1.3E+00
Na-22	1.3E+00	1.3E+00	3.0E-01	3.0E-01
U-233	1.2E+00	1.2E+00	1.1E+00	1.1E+00
Mo-99	1.0E+00	1.0E+00	1.0E+00	1.0E+00
Pr-143	0	1.5E+03	1.2E+03	6.2E+02
Y-91	0	1.3E+03	1.0E+03	5.3E+02
Tc-99	2.5E-06	8.8E+02	5.2E+02	2.6E+02
Rh-103m	0	6.6E+02	5.4E+02	2.7E+02
Cm-242	0	7.3E-01	1.7E+02	9.1E+01
I-129	0	5.0E-02	1.9E-01	9.9E-02
Cm-244	9.8E-04	3.4E-01	1.4E+02	8.0E+01
U-234	1.8E-01	1.8E-01	6.8E+01	6.4E+01
Zr-93	0	0	4.0E+00	4.0E+00
Tm-170	0	0	3.4E+00	3.4E+00
Ba-137m	1.7E-01	1.7E-01	3.4E+00	3.4E+00
U-236	4.0E-03	4.0E-03	3.9E+00	2.5E+00
Np-237	6.0E-03	6.0E-03	4.6E+00	2.4E+00
Th-232	2.5E-01	2.5E-01	1.3E+00	1.3E+00
Cs-136	1.6E-01	1.6E-01	1.5E+00	7.7E-01
Total	1.1E+07	1.1E+07	1.7E+07	1.2E+07

Radionuclides were included in the comparison if their activity listed in RWMIS was at least 1 Ci. Additional radionuclides were included at the end of the list if their activity in the CIDRA database was at least 1 Ci, before correction for the bias in the G-M counter readings. In addition, I-129 was included because although its activity was very small, it is very long-lived and relatively mobile when released from confinement.

To compare the CIDRA and RWMIS entries, the generic terms had to be eliminated from the RWMIS entries. The activity represented by the generic terms was broken down as described in Section 6.2.3.1, leading to the values in the third column of Table 6-5. Also, dual radionuclide entries in RWMIS, such as Zr-Nb-95, were assigned as described in Appendix E. (Section 3.1.1 discusses the treatment of secular equilibrium in the CIDRA inventory and in the risk assessment.) The third column, therefore, represents the radionuclide inventory if RWMIS is used and the generic terms and dual radionuclide entries are broken down into their constituent radionuclides, following the general methods used in the HDT study.

The fourth column gives the CIDRA values for the same radionuclides. The data in this column do not reflect the corrections made for the bias in inventory information based on the G-M counter surveys of waste containers. Thus, the data in this column are not the final CIDRA data, but they are a version used only to check for completeness against the RWMIS values.

6.2.3.3 Comparisons of Results Before Applying Corrections to Activity Estimates Derived from Geiger-Müller Counter Survey Data. The third and fourth columns of Table 6-5 allow comparisons of the results from CIDRA with those from RWMIS. The generic radionuclide terms in RWMIS are distributed using a simplified version of the CIDRA results, but without the effect of the corrections to data originally obtained from the G-M counter surveys. The following paragraphs discuss the results for only the predominant radionuclides. For both databases, data rollups by generator were consulted in evaluating the results, but generally they are not presented here for brevity.

The nuclide-by-nuclide comparisons are discussed most easily by grouping the radionuclides according to fission products, activation products, and actinides. (Actinides include actinium and higher-numbered elements on the Periodic Table, such as plutonium, americium, and uranium.) Tritium (H-3) is a special case and is addressed first.

Tritium (H-3)—The CIDRA value is approximately 20 times larger than the RWMIS entry with the generic entries distributed. [Compared with the unmodified RWMIS inventory (i.e., without the generic entries distributed), the CIDRA H-3 entry is about 140 times larger.] This difference is to be expected. Section 2.4.2 explained that waste stream TRA-670-1H is the beryllium reflectors from ATR, MTR, and ETR. This stream contains nearly all of the CIDRA H-3 inventory. The H-3 activation product was not reported on the shipping records and is, therefore, not in RWMIS. Tritium is a pure beta-emitter, and its activity in a metallic matrix is very difficult to measure by conventional health physics instrumentation.

Fission Products—For the nine fission products that constitute nearly all of this type of activity, the CIDRA and RWMIS values are compared below. The order is the same as their ranking as reported estimates in CIDRA.

The *total* activities of these nine principal fission products in CIDRA and RWMIS are within about 20% (2.2 million Ci and 1.8 million Ci, respectively). This difference is less than the total random error for the estimated activity of the radionuclides in an individual waste shipment. The *distributions* of the fission products differ markedly, however, because most of the CIDRA values are based on nuclear physics calculations involving actual or assumed histories of nuclear reactor cores. Accordingly, the comparisons of some individual nuclides below involve differences considerably larger than 20%.

- **Cs-137.** The CIDRA value is 20% larger than the RWMIS value. The difference is less than the total random error for estimating the radioactivity in an individual waste shipment. Most of the Cs-137 is from TRA, NRF, and ANL-W.

- **Sr-90.** The CIDRA value is almost twice the RWMIS value. Most of the Sr-90 is from ANL-W, NRF, and TRA.

- **Ce-144.** The CIDRA value is about 35% smaller than the RWMIS value because of the assumed distribution of the MFP entries in RWMIS. Most of the Ce-144 is from ANL-W.

- **Sb-125.** The CIDRA value is 8% larger than the RWMIS value. The difference is less than the total random error for estimating the radioactivity in an individual waste shipment. Most of the Sb-125 is from NRF.

- **Pr-144.** The CIDRA value is about 45% larger than the RWMIS value. The Pr-144 is from CPP.

- **Eu-155.** The CIDRA value is about 6% smaller than the CIDRA value. The difference is less than the total random error for estimating the radioactivity in an individual waste shipment. Most of the Eu-155 is from TRA.

- **Sn-119m.** The CIDRA value is 35% larger than the RWMIS value. The Sn-119m is from NRF.

- **Y-90.** The CIDRA value is about 35% larger than the CIDRA value. As explained in Section 3.1, Y-90 is a short-lived decay product of Sr-90. Secular equilibrium is established quickly between the two radionuclides. Some preparers of waste information included the Y-90; some did not. The lack of full reporting of Y-90 is not important to the BRA; the calculations of radioactive decay to be performed in conjunction with the BRA will reflect equilibrium and the appropriate activity of Y-90.

- **Ce-141.** The CIDRA value of 1,500 Ci is about 1/20 of the RWMIS value of 30,000 Ci. In RWMIS, 28,000 Ci of the 30,000 Ci is from TRA. In CIDRA, TRA reported only 3 Ci of Ce-141; most of the 1,500 Ci in CIDRA is from TAN. With a half-life of only 32.5 days, the 30,000 Ci of Ce-144 was reduced to approximately 30 Ci within 325 days after reporting and has now decayed to < 1 Ci in activity. The large difference in reported activities between RWMIS and CIDRA is probably due to a difference in the convention regarding the reporting of very short-lived radionuclides. The difference is of no consequence for the BRA.

Iodine-129 is not one of the top nine fission products in CIDRA in terms of activity. However, I-129 is important to the BRA because of its very long half-life (15.7 million years) and its potential for a comparatively high mobility in subsurface transport. The CIDRA value for I-129 is 0.19 Ci, almost entirely from TRA. The activity was estimated by means of the nuclear physics calculations described in Section 2.4.2. The RWMIS value is 0 before distributing the MFP and unidentified beta-gamma emitters and 0.05 Ci after. Iodine-129 is seldom reported in waste shipments because it is very difficult to measure (EPRI 1987).

For the principal fission products and for the fission products as a whole, the comparison against the data in RWMIS confirmed that the CIDRA inventory of fission products is substantially complete. The only principal fission products for which the CIDRA values are substantially smaller than the RWMIS values are Ce-144 and Ce-141. The half-lives of these two radionuclides are only 284.6 and 32.5 days, respectively.

Activation Products. For the nine activation products that constitute nearly all of this type of activity, the CIDRA and RWMIS values are compared below. The order is the same as their ranking as reported estimates in CIDRA.

The total activity for these nine principal activation products in CIDRA is about 50% higher than the corresponding total in RWMIS (13.0 million versus 8.7 million Ci). Again, the distributions differ markedly because most of the CIDRA values are based on nuclear physics calculations involving actual or assumed operating histories of nuclear reactor cores. Accordingly, the comparisons of some individual nuclides below involve differences larger than 50%.

- **Fe-55.** The CIDRA value is almost 20 times larger than the RWMIS value. Most of the Fe-55 is from TRA. The reason for the large increase in the estimated activity of Fe-55 is given in Tables 2-8 and 2-10 and is repeated here. Laboratory data (e.g., EPRI 1987) show that Fe-55 is a predominant contributor to the activity in certain types of LLW. Iron-55 emits no gamma radiation, so it does not contribute to the activity detected by the G-M method. This is why the scaling factors used here for those types of waste total more than unity.

- **Co-60.** The CIDRA value is about 2% smaller than the RWMIS value. The difference is less than the total random error for estimating the radioactivity in an individual waste shipment. Most of the Co-60 is from TRA and NRF.

- **Ni-63.** The CIDRA value is almost 3 times larger than the RWMIS value. Most of the Ni-63 is from TRA. The reason for the large increase in the estimated activity of Ni-63 is the same as that for Fe-55.

- **Cr-51.** The CIDRA value about one-third of the RWMIS value. Most of the Cr-51 is from TRA.

- **Mn-54.** The CIDRA value is about one-third of the RWMIS value. Most of the Mn-54 is from ANL-W and CPP.

- **Co-58.** The CIDRA value is about one-fourth of the RWMIS value. Most of the Co-58 is from CPP and ANL-W.

- **Fe-59.** The CIDRA value is about one-third of the RWMIS value. Most of the Fe-59 is from TRA and CPP.

- **Zr-95.** The CIDRA value is about one-fifth of the RWMIS value. Most of the Zr-95 is from NRF.

- **C-14.** The CIDRA value is 32,000 Ci, virtually all of which is from TRA. The RWMIS value before distributing the generic entries is only 3.9 Ci; virtually all of the C-14 came from offsite and none was reported from TRA. The simple method for distributing the generic entries increases the RWMIS value to 8,500 Ci. Carbon-14 is very difficult to measure in waste shipments; evidently, nuclear physics calculations were not performed to support the TRA data submittal to RWMIS.

Technetium-99 and Nb-94 are not among the top nine activation products in CIDRA in terms of activity. However, they are important to the BRA because of their very long half-lives (5,730 years for C-14 and 20,000 years for Nb-94) and their potential for comparatively high mobilities in subsurface transport. Their activities are discussed below.

The CIDRA value for Tc-99 is 520 Ci, almost all of which is from TRA. The RWMIS value before distributing the generic entries is <1 Ci. The simple method for distributing the generic entries increases the RWMIS value to 880 Ci. The reason why Tc-99 was underreported on the shipping records is the same as that stated for C-14.

The CIDRA value for Nb-94 is 49 Ci, with 47 Ci generated by CPP and 2 Ci generated by D&D activities. The RWMIS value is only the 2 Ci from D&D. The reason why Nb-94 was underreported on the shipping records is the same as that stated for C-14.

Among the principal activation products, the CIDRA inventory is substantially less than that in RWMIS only for Cr-51, Mn-54, Co-58, Fe-59, and Zr-95. The half-lives of these radionuclides are all less than 1 year. Thus, the CIDRA values are either much larger than or similar to the RWMIS values for all principal activation products with half-lives greater than 1 year. As a result, for the principal activation products and for the activation products as a whole, the comparison against the data in RWMIS confirmed that the CIDRA inventory of activation products is substantially complete.

Actinides. For the 11 actinides that constitute nearly all of this type of activity, the CIDRA and RWMIS values are compared below. The sequence departs slightly from their ranking as reported estimates in CIDRA so that closely related radionuclides could be discussed consecutively.

The total activity for these 11 principal actinides in CIDRA is much higher than the corresponding total in RWMIS (640,000 versus 60,000 Ci). The difference in the total is due almost entirely to the new, increased estimates of activity in the RFP waste (which is almost exclusively from actinides) and to the incompleteness of the early RWMIS records.

- **Pu-241.** The CIDRA value is approximately 12 times the RWMIS value. The Pu-241 is almost entirely from RFP.

- **Am-241.** The CIDRA value is approximately 7-1/2 times the RWMIS value. The Am-241 is almost entirely from RFP.

- **Pu-239.** The CIDRA value is approximately 14 times the RWMIS value. The Pu-239 is almost entirely from RFP.

- **Pu-240.** The CIDRA value is approximately 10 times the RWMIS value. The Pu-240 is almost entirely from RFP.

- **Pu-238.** The CIDRA value is approximately 16 times the RWMIS value. The Pu-238 is almost entirely from RFP.

- **U-238.** The CIDRA value is more than twice the RWMIS value. Most of the U-238 came from RFP and was disposed of either in the pits and trenches or on Pad A.

- **U-234.** The CIDRA value is 68 Ci, mostly from RFP. RWMIS lists < 1 Ci of U-234. The reason for the large difference is that the uranium-234 in CIDRA was estimated based on nuclear physics calculations. U-234 exists in all uranium, in a concentration that depends on the enrichment, but the U-234 was seldom reported on shipping records.

- **U-235.** The CIDRA value is much smaller than the RWMIS value (5.2 Ci versus 710 Ci). The difference is almost entirely due to an error in a single shipping record that was entered into RWMIS. The record related to NRF waste shipped in 1965. The radionuclide entry on that particular shipping record should have read "700 Ci of mixed fission products with a trace of U-235" instead of "700 Ci of U-235." The discrepancy is discussed in detail in Nieslanik (1994). Deleting this erroneous entry from RWMIS would result in the CIDRA and RWMIS values for U-235 agreeing to within about 5 Ci.

- **Cm-242.** The CIDRA value is 170 Ci, almost entirely from TRA. RWMIS does not list any Cm-242. The reason for the large difference is that the Cm-242 in CIDRA was estimated based on nuclear physics calculations.

- **Cm-244.** The CIDRA value is 140 Ci, almost entirely from TRA. RWMIS lists < 1 Ci. The reason for the large difference is that the Cm-244 in CIDRA was estimated based on nuclear physics calculations.

- **Ra-226.** The CIDRA value is 69 Ci, mostly from the miscellaneous offsite generators. The RWMIS value is 30 Ci.

Neptunium-237 is not among the top 11 activation products in CIDRA in terms of activity. However, Np-237 is important to the BRA because of its very long half-life (2.14 million years). The CIDRA value is 4.6 Ci, almost all from TRA. The RWMIS value is 0.006 Ci. The reason for the difference is that the Np-237 in CIDRA was estimated based on nuclear physics calculations.

Thus, the CIDRA entries for the actinides are all larger than the corresponding RWMIS values, except for the erroneous RWMIS record for U-235.

Total Inventory—The total activity in CIDRA (without the G-M corrections) is 17 million Ci; the total inventory in RWMIS is 11 million Ci. The relative value of these two totals indicates that CIDRA is not missing any large inventory entries.

Conclusion—For the principal, longer-lived nuclides (i.e., half-lives beyond 1 year) in each segment of the inventory—fission products, activation products, and actinides—the total activity in CIDRA is similar to or larger than that in RWMIS. In addition, the total inventory in CIDRA is substantially larger than that in RWMIS. Therefore, the results of these comparisons of CIDRA values (without the G-M correction) against RWMIS values (with the generic activity terms distributed) confirm that the HDT has not overlooked any substantial radioactivity in the waste.

6.2.3.4 Comparisons of Results After Applying the CIDRA Corrections for Geiger-Müller Counter Survey Data. The third and fifth columns of Table 6-5 allow comparisons of CIDRA and RWMIS results, including the effect of the corrected data from G-M counter surveys. Because of the corrections made to some of the values taken from the records, this comparison is less useful than the preceding one in identifying possible oversights in CIDRA. However, the comparison is useful to show the overall change in contaminant inventory. The following paragraphs discuss the impacts of the corrections in reference to the comparisons against RWMIS.

The correction to the data derived from G-M counter surveys reduces the activities of certain radionuclides in the CIDRA inventory. This reduction arises in the following way. For individual waste streams from generators other than the RFP, the reduction ranges from no change to a factor of two. If the uncertainty in contaminant quantity was specified by the data gatherer, based on consideration of how the estimates or measurements were made originally, the G-M correction is not applied. If no uncertainty was specified (because the standard G-M counter method was believed to have been used), all activities in the waste stream were divided by two.

If all waste streams contributing to the inventory of a given radionuclide were subject to the factor of two reduction, then the total inventory of that radionuclide (last column of Table 6-5) reflects a reduction by a factor of two, compared with the entry in the preceding column. For example, such is the case for Ru-103. On the other hand, if none of the contributory streams were subject to the correction, then the entries in the last two columns are identical. For example, the Pu-239 comes almost entirely from RFP waste streams, in which a calculational method was used rather than the G-M counter survey method. The entries for Pu-239 in the last two columns are, therefore, identical. For most radionuclides, the amount of the correction falls between these two extremes.

For radionuclides not affected by the G-M counter correction, such as Pu-239, the discussion in the previous comparison against RWMIS still applies. For radionuclides strongly affected by the correction, the CIDRA quantity is reduced by as much as a factor of two, and the comparison against RWMIS is similarly affected.

Applying the G-M counter correction reduces the total activity in CIDRA from 17 million to 12 million Ci, approximately 9% larger than RWMIS.

6.2.4 Comparisons at the Level of Individual Generators, Summed Over All Radionuclides

6.2.4.1 Approach. The RWMIS annual summaries were used for most of the comparisons at the level of individual generators. The results from the RWMIS shipping record rollups are also useful for comparison.

The methods used for these comparisons were basically the same as those described in Section 6.2.3. The principal difference is that the total radioactivity in the waste from each major generator in 1952 through 1983 is given.

Again, it is stressed that the comparisons presented here are for the purpose of confirming the general completeness of CIDRA. The comparisons are not intended to drive the totals from CIDRA to match those in RWMIS because CIDRA contains significantly improved information that is not found in RWMIS.

6.2.4.2 Comparisons. Table 6-6 provides the results of these comparisons. For confirming the completeness of CIDRA and for understanding the nature of the data-gathering process, the column containing the CIDRA reported estimates (no G-M correction) is compared with the two columns to the left of it. The last column is shown only for perspective. The comparisons are discussed in terms of approximate numbers because of rounding all totals to two significant figures.

- **TAN.** The CIDRA value of 70,000 Ci for the total radioactivity in TAN waste lies between the two RWMIS values of 63,000 and 100,000 Ci. The differences relate primarily to assumptions made about the activity in the waste from 1956 through 1962. Waste generated in these years involved almost one-half of the radioactivity in TAN waste; in addition, these years were during the period when the shipping records were incomplete. As expected, the RWMIS shipping records rollup is the smallest of the three values for TAN. The TAN lead data gatherer for CIDRA used judgment based on knowledge of the operations at TAN during each year to assign the annual values of radioactivity listed in Table 2-4. The annual summaries for TAN that were entered into RWMIS in 1971 evidently were still larger than those in Table 2-4. The persons who entered those data in 1971 evidently assigned a higher fraction of the total NRTS radioactivity to TAN than did the CIDRA data gatherer.

- **TRA.** The CIDRA value of 11 million Ci for the total radioactivity in TRA waste is larger than the RWMIS values of 3.9 million and 4.6 million Ci. (Interestingly, the RWMIS shipping record rollup gives a larger value than do the RWMIS annual summaries.) Part of the difference is due to stream TRA-670-1H, the beryllium reflectors. The H-3 in this stream, which amounts to an estimated 1,049,500 Ci, is not included in the RWMIS records. The remainder of the difference is due primarily to the use of activity scaling factors that sum to greater than unity, as explained in Tables 2-8 and 2-10.

- **ICPP.** The CIDRA value of 690,000 Ci is somewhat larger than the two RWMIS values of 610,000 Ci. For several waste streams, the ICPP lead data gatherer for CIDRA obtained radioactivity data from other information sources that added to the values given in RWMIS. One example is a waste stream generated in 1959 involving contaminated soil, a stream that is not in RWMIS because of the gaps in the shipping records.

Table 6-6. Radioactivity totals as given by RWMIS annual summaries and shipping record rollups, and by CIDRA (with and without Geiger-Müller counter corrections).

Major generator	RWMIS annual summaries (Ci)	RWMIS shipping record rollups (Ci)	CIDRA reported estimates (no G-M corrections) (Ci)	CIDRA best estimate (with G-M corrections) (Ci)
TAN	1.0E+05	6.3E+04	7.0E+04	3.5E+04
TRA	3.9E+06	4.6E+06	1.1E+07	6.6E+06
ICPP	6.1E+05	6.1E+05	6.9E+05	6.9E+05
NRF	3.7E+06	4.2E+06	3.2E+06	2.9E+06
ANL-W	1.1E+06	1.1E+06	1.1E+06	1.1E+06
RFP	2.6E+05	5.7E+04	6.2E+05	6.2E+05
Other[a]	1.1E+05	5.5E+04	5.3E+04	4.9E+04
Total	9.7E+06	1.1E+07	1.7E+07	1.2E+07

a. Includes the 38 Ci on Pad A from all generators.

- **NRF.** The CIDRA value of 3.2 million Ci is somewhat smaller than the RWMIS values of 3.7 million and 4.2 million Ci. The difference of about 15% to 20% is considered to be within the uncertainty of the inventory approaches used.

- **ANL-W.** The CIDRA value of 1.1 million Ci matches the RWMIS values.

- **RFP.** The CIDRA value of 620,000 Ci for the total radioactivity in RFP waste is much larger than the RWMIS values of 57,000 and 260,000 Ci. As discussed in Section 2.4.6 and Appendix C, the improved method for estimating the inventory of contaminants in waste from the RFP did not involve the use of RWMIS (except for shipments of depleted uranium in 1971–1972, which were very small in radioactivity). The method involved the use of plantwide inventory balances at the RFP. The much higher values that appear in CIDRA are not surprising and are considered to be the most reliable estimates available.

- **Other.** The CIDRA value of 53,000 Ci for the total radioactivity in waste from the other generators is nearly identical to the value of 55,000 Ci in the RWMIS shipping record rollup. The value of 110,000 Ci found in the RWMIS annual summaries is inappropriate

for comparison. It includes 61,000 Ci that was attributed in 1971 to the RWMC itself as a waste generator, because the 61,000 Ci was generated by unknown onsite generators. That is, in using the RWMIS annual summaries, the 61,000 Ci ascribed to the RWMC should probably be apportioned over TAN, TRA, ICPP, NRF, and ANL-W. Subtracting the 61,000 Ci from the other generator category would reduce the RWMIS annual summaries value to 51,000 Ci, which is slightly smaller than the 53,000 Ci in CIDRA and the 55,000 Ci in the RWMIS shipping record rollup.

In summary, the generator-by-generator comparisons provide expected results considering the nature of the present inventory compilation and the uncertainties involved.

6.3 Comparison of the Inventory with Contaminants Detected in Environmental Monitoring

6.3.1 Purpose

It is useful to compare the estimated inventory of contaminants in CIDRA with the list of contaminants whose presence is detected at the RWMC by means of environmental monitoring. Potential gaps in the inventory may, thereby, be identified.

The following sections include (a) the approach used to analyze contaminant monitoring results, (b) a summary of routine environmental monitoring activities and of special studies not part of the routine monitoring, (c) a brief summary of the monitoring results in terms of contaminants detected, years, and environmental media, and (d) comparisons of contaminants detected against the contaminant inventory in CIDRA for the historical and recent periods. [Because the environmental monitoring may detect contaminants disposed of during either the historical period (1952 through 1983) or the recent period (1984 through 2003), the comparison was performed simultaneously for the inventory of both periods.] The documents from which the monitoring summaries were produced are listed in the bibliography in Appendix F.

6.3.2 Approach

Pertinent monitoring data for the RWMC were obtained from two primary sources: (a) annual summary reports for routine monitoring and (b) documentation for special environmental studies. Routine monitoring results for the environmental monitoring program have been summarized annually since 1976. Concentrations are measured for radiological and nonradiological contaminants in air, soil, water, geologic media, and biotic media. These data were examined and summarized for the years 1976 through 1993. Existing databases and documents were consulted to identify special studies conducted on the SDA that resulted in reported environmental concentrations for radiological or nonradiological contaminants. Routine monitoring and special study results were evaluated by contaminant and medium and were summarized. The monitoring results were compared with the list of contaminants in the CIDRA inventory. The results of the comparison were interpreted with respect to the completeness of the list of contaminants in the inventory.

6.3.3 Environmental Monitoring Program

A comprehensive monitoring program is conducted at the RWMC and other areas of the INEL. The program provides for routine monitoring and data interpretation of radioactive and nonradioactive contaminants in the environment associated with the RWMC and SDA (Wilhelmsen et al. 1994).

Routine monitoring activities conducted as part of the program for the RWMC and SDA are summarized in Table 6-7. The program includes measuring the concentrations of radioactive contaminants in air, water, soil, and biota (vegetation and small mammals), as well as monitoring of ambient radiation (Wilhelmsen et al. 1994). Monitoring conducted by RESL and groundwater monitoring activities conducted by the U.S. Geological Survey (USGS) are incorporated into the program and included in the annual summary reports. Nonradiological contaminants—metals and organics in liquid effluents and drinking water—are also assessed.

6.3.4 Special Studies

A number of special or one-time environmental studies for radiological and nonradiological contaminants have been performed at the RWMC and SDA. Data collected as part of the RWMC Subsurface Investigations Program, USGS studies, and other contaminant investigative studies were reviewed and summarized. Investigations included subsurface drilling, soil vapor monitoring, and groundwater monitoring. Data from the studies included in this HDT date back as far as the mid-1970s.

6.3.5 Summary of Monitoring Results

The results of routine monitoring and special studies for radiological and nonradiological contaminants in the SDA are summarized in Appendix F.

6.3.6 Comparison of Contaminants Detected in Monitoring Activities Against Contaminants Identified in the Waste Inventory

Table 6-8 compares the results from environmental monitoring against the results of the inventory compilation for the historical and recent periods. The table lists the contaminants detected in routine monitoring or in special studies, the presence of each contaminant in the waste inventory, the media in which the contaminants were detected, the years in which they were detected, and brief conclusions concerning the comparisons (i.e., monitoring reliability and the qualitative amount of the contaminant in historical and recent periods). The table lists radiological contaminants first, followed by nonradiological contaminants.

6.3.6.1 Radiological Contaminants. No radiological contaminants that were reliably detected during monitoring were missing from the waste inventory.

The following radiological contaminants were detected in reliable data from the monitoring and were identified in the waste inventory: Am-241, Co-60, Cs-134, Cs-137, H-3, Pu-238, Pu-239/240, Sb-125, Sr-90, U-234, U-235, and U-238.

Table 6-7. Routine environmental monitoring activities performed at the Subsurface Disposal Area (compiled from Wilhelmsen et al. 1994).

Activity	Facility	Description	Frequency of analysis	Type of analysis
RADIOLOGICAL CONTAMINANTS				
Ambient air monitoring	SDA	Eight low-volume air samples operated at 0.14 m^3/min (includes one control and one replicate)	Semimonthly Semimonthly Monthly Quarterly	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a]
Soil sampling	SDA	Five locations in each of five major areas (plus one control area)	Triennially	Gamma spectrometry Radiochemistry[a]
Subsurface water (sampled by the USGS)	SDA	2-L samples from each of six wells (five wells to the aquifer, one well to perched water)	65-m (perched water) well annually 183-m (aquifer) wells quarterly Production well quarterly	Gamma spectroscopy, chlorides (i.e., Cl-35), H-3, Sr-90, Co-60, Cs-137, Pu-238, Pu-239/240, and Am-241
Surface water sampling	SDA	4-L surface runoff samples from SDA and control location	Quarterly, but depends on precipitation	Gross alpha Gross beta Gamma spectrometry Radiochemistry[a,b,c]
Biotic surveillance	SDA and TSA	Small mammals—three composites in each of five major areas (plus one control area)[c]	Annually, but species sampled varies each year depending on availability	Gamma spectrometry Radiochemistry[a]
		Vegetation—three composites in each of five major areas (plus one control area)[c]	Annually, but species sampled varies each year depending on availability	Gamma spectrometry Radiochemistry[a]
		Small mammal burrow excavations (soil)—three composites from each of five major areas	Annually	Gamma spectrometry Radiochemistry[a]
NONRADIOLOGICAL CONTAMINANTS				
Subsurface water (sampled by the USGS)	SDA	Drinking water	Production well monthly	Organics Specific conductance Chloride, sodium, nitrate

a. Analysis for Am-241, Pu-238, Pu-239/240, U-235, U-238, and Sr-90.

b. Samples for radiochemical analyses usually taken during second quarter only.

c. Exact number of samples may vary because of availability.

Table 6-8. Comparison of results of environmental monitoring against results of the inventory compilation.

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
RADIOLOGICAL					
Ac-228	No	No	Aquifer	1979	Not identified in waste for either period; monitoring detections not reliable
Ag-110	Yes	Yes	Air	1980	Minute quantities identified in waste for both time periods; monitoring detections not reliable
			Surface water	1977	
			Soil	1979, 80	
Am-241	Yes	Yes	Aquifer	1976, 81, 82, 84, 87	Very large and small quantities identified in waste for historical period and for recent period, respectively; detected frequently in monitoring program
			Surface water	1977, 83–85, 90–93	
			Subsurface sediment	1975–77, 85–88, 89	
			Surficial sediment	1989	
			Soil	1977–81, 84, 86, 88, 91, 92	
			Biota—vegetation	1984, 86, 87, 90–93	
			Biotic—soil	1984–86, 90	
			Biotic—tissue	1987, 89	
			Air	1978–81, 84–93	
Ba-140	Yes	Yes	Air	1980	Small and minute quantities identified in waste for historical period and for recent period, respectively; monitoring detections not reliable
Ce-141	Yes	Yes	Aquifer	1983	Small and minute quantities identified in waste for historical period and for recent period, respectively; monitoring detections not reliable
			Surface water	1977, 81	
			Soil	1979–81	
			Air	1978–81, 83–84	
Ce-144	Yes	Yes	Subsurface sediment	1975–78	Very large and moderate quantities identified in waste for historical period and for recent period, respectively; monitoring detections not reliable
			Surface water	1976–79	
			Soil	1978–81	
			Air	1978–81, 83–84	

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952-1983)	Contaminant present in inventory? (recent period 1984-1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Co-58	Yes	Yes	Soil	1978-81	Very large quantities identified in waste for both time periods; most monitoring detections not reliable
			Air	1978-81, 83, 85	
Co-60	Yes	Yes	Aquifer	1980, 87	Very large quantities identified in waste for both time periods; detected frequently in monitoring program
			Perched water	1976-77	
			Subsurface sediment	1976-88, 89	
			Surface water	1977	
			Surficial sediment	1989	
			Soil	1977-81, 86	
			Biota—vegetation	1983	
			Biotic—soil	1984	
			Biotic—tissue	1987, 91, 92	
			Air	1978-81, 83, 86	
Cr-51	Yes	Yes	Surface water	1977	Very large and large quantities identified in waste for historical and recent periods, respectively; monitoring detections not reliable
			Soil	1978-81	
			Air	1978-81, 83	
Cs-134	Yes	Yes	Surface water	1977, 79, 81	Moderate and small quantities identified in waste for historical and recent periods, respectively; detected occasionally in monitoring program
			Soil	1978-81	
			Biota—vegetation	1987	
			Air	1978-81, 85	
Cs-137	Yes	Yes	Aquifer	1976, 77, 80, 86, 87	Very large and moderate quantities identified in waste for historical and recent periods, respectively; detected frequently in monitoring program
			Perched water	1976, 77	
			Subsurface sediment	1975-88, 89	
			Surface water	1976, 77, 79-81, 83-86, 88, 90, 93	
			Surficial sediment	1989	
			Soil	1977-81, 84, 88, 89, 92	
			Biota—vegetation	1983, 84, 87	
			Biotic—soil	1984, 86, 90	
			Biotic—tissue	1987, 91, 92	
			Air	1978-81, 84-85, 87, 91	

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952-1983)	Contaminant present in inventory? (recent period 1984-1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Eu-152	Yes	Yes	Surface water Soil Biotic—tissue Air	1976, 78-79 1978-81 1987 1978-81	Small and minute quantities identified in waste for historical and recent periods, respectively; most monitoring detections not reliable
Eu-154	Yes	Yes	Subsurface sediment Surface water Surficial sediment Soil Biotic—tissue Air	1985 1976, 79 1989 1978-81, 89 1987 1978-81	Moderate and minute quantities identified in waste for historical and recent periods, respectively; most monitoring detections not reliable
Eu-155	Yes	Yes	Soil Air	1981 1981	Large and minute quantities identified in waste for historical and recent periods, respectively; monitoring detections not reliable
Fe-59	Yes	Yes	Aquifer Soil Air	1976 1979-81 1978-81	Large quantities identified in waste for both time periods; monitoring detections not reliable
H-3	Yes	Yes	Aquifer Perched water	1977-93 1976-77, 92, 93	Very large quantities identified in waste for both time periods; detected frequently in monitoring program
Hf-181	Yes	Yes	Soil Air	1978-81 1978-81	Minute and moderate quantities identified in waste for historical and recent periods, respectively; monitoring detections not reliable
Hg-203	Yes	No	Soil Air	1980-81 1978-81	Minute and no quantities identified in waste for historical period and recent period, respectively; monitoring detections not reliable
I-131	Yes	Yes	Air	1980	Minute quantities identified in waste for both time periods; monitoring detections not reliable

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952-1983)	Contaminant present in inventory? (recent period 1984-1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Mn-54	Yes	Yes	Aquifer Soil Air	1977 1979-81 1978-81, 83	Very large quantities identified in waste for both time periods; monitoring detections not reliable
Nb-95	Yes	Yes	Surface water Soil Air	1977 1978-81 1978-81	Moderate quantities identified in waste for both time periods; monitoring detections not reliable
Pb-212	Yes	No	Aquifer	1978	Minute and no quantities identified in waste for historical period and recent period, respectively; monitoring detections not reliable
Pu-238	Yes	Yes	Aquifer Perched water Subsurface sediment Surface water Surficial sediment Soil Soil water Biota—vegetation Biotic—tissue Air	1981, 83, 87 1976, 77, 89 1975-89 1983 1989 1979-81, 88, 89, 91, 92 1989 1984, 86-87, 90 1987, 89 1980, 86-88	Large and small quantities identified in waste for historical period and recent period, respectively; detected frequently in monitoring program
Pu-239/240	Yes	Yes	Aquifer, perched Subsurface sediment Surface water Surficial sediment Soil Soil water Biota—vegetation Biotic—soil Biotic—tissue Air	1976, 85-89 1975-78, 85-88, 89 1983-85 1989 1976-77, 79-81, 86, 88, 89, 91-93 1989 1986-87, 90 1984, 86-90 1987, 89 1980, 84-88, 90-93	Very large and small quantities identified in waste for historical period and recent period, respectively; detected frequently in monitoring program

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Ru-103	Yes	Yes	Surface water Soil Air	1977, 81 1978–81 1978–80, 83	Small and minute quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable
Ru-106	Yes	Yes	Surface water Soil Biota—vegetation Air	1976–77, 79 1979, 81 1978 1978–81	Moderate and small quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable
Sb-124	Yes	Yes	Soil Air	1979–81 1979–81	Moderate and minute quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable
Sb-125	Yes	Yes	Surface water Soil Biota—vegetation Biotic—tissue Air	1978–81 1978–81 1987 1987 1978–81, 84	Very large and moderate quantities identified in waste for the historical and recent periods, respectively; detected occasionally in monitoring program, but early detections not reliable
Sc-46	Yes	Yes	Soil Air	1979–81 1978–81	Minute quantities identified in waste for both time periods; monitoring detections not reliable
Sr-90	Yes	Yes	Aquifer, perched Subsurface sediment Surface water Surficial sediment Soil Biota—vegetation Biotic—tissue Biotic—soil Air	1976, 78–80, 85–88 1975–88, 89 1987 1989 1988, 89, 91, 92 1983, 84, 86, 87, 90, 92, 93 1987, 89 1984 1986–88, 93	Very large and small quantities identified in waste for the historical and recent periods, respectively; detected frequently in monitoring program

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Ta-182	Yes	Yes	Soil Air	1979–81 1979–81	Minute and large quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable
U-234	Yes	Yes	Soil Biota—vegetation Biotic—tissue	1986, 92 1985, 87 1987	Small quantities identified in waste for both time periods; detected occasionally in monitoring program
U-235	Yes	Yes	Soil Biota—vegetation Biotic—tissue	1983 1987 1987, 89	Small quantities identified in waste for both time periods; detected rarely in monitoring program
U-237	No	No	Air	1980	Not identified in waste for either time period; monitoring detections not reliable
U-238	Yes	Yes	Soil Biota—vegetation Biotic—tissue	1983–84, 92 1987 1987, 89	Moderate and small quantities identified in waste for the historical and recent periods, respectively; detected rarely in monitoring program
Y-91	Yes	No	Soil Air	1979–80 1979–80	Small and no quantities identified in waste for historical period and recent period, respectively; monitoring detections not reliable
Zn-65	Yes	Yes	Soil Air	1979–81 1978–81	Small and moderate quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable
Zr-95	Yes	Yes	Soil Air Surface water	1979–81 1978–81 1977	Large and moderate quantities identified in waste for the historical and recent periods, respectively; monitoring detections not reliable

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
NONRADIOLOGICAL					
Organics[e]					
1,1,1-trichloroethane	Yes	No	Aquifer, perched Soil borehole (vapor) Soil/soil gas Air	1987–93 1987, 88 1987 1991, 94	Very large quantity identified in waste for the historical period; detected frequently in monitoring program
1,1,2-trichloro-trifluoroethane	Yes	No	Perched water Soil borehole (vapor) Soil/soil gas Air	1987–90 1987 1987 1989	Large quantity in waste for the historical period; detected frequently in monitoring program
1,1-dichloroethylene	No	No	Aquifer, perched	1987–93	Not specifically identified in inventory; detected frequently in monitoring program
1,1-dichloroethane	No	No	Aquifer, perched	1987–93	Not specifically identified in inventory; detected frequently in monitoring program
2-butanone	Yes	No	Air	1994	Moderate quantity identified in the waste for the historical period; previous instruments were not capable of measuring low concentrations of 2-butanone
Acetone	Yes	No	Sedimentary interbed Air	1987 1994	Large quantity identified in waste for the historical period; detected rarely in monitoring program
Carbon tetrachloride	Yes	No	Aquifer, perched Borehole (vapor) Soil/soil gas Air	1987–93 1987–88 1987, 92 1987, 89	Very large quantity identified in waste for the historical period; detected frequently in monitoring program
Chloroform	Yes	No	Aquifer, perched Soil/borehole (vapor) Sedimentary interbed Air	1987–93 1987–88, 92 1987 1989, 94	Very large (unknown) quantity identified in waste for the historical period; detected frequently in monitoring program

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Organics (continued)					
Dichlorodifluoromethane	No	No	Aquifer, perched Air	1987–93 1994	Not specifically identified in inventory; detected frequently in monitoring program
Methylene chloride	Yes	No	Sedimentary interbed Perched water Air	1987 1993 1991, 94	Very large quantity in waste for the historical period; detected rarely in monitoring program
Phenol	No	No	Aquifer	1991	Not specifically identified in inventory; detected rarely in monitoring program
Tetrachloroethylene	Yes	No	Aquifer, perched Soil/borehole (vapor) Soil/soil vapor Air	1987–93 1987, 92 1987 1994	Very large quantity identified in waste for the historical period; detected frequently in monitoring program
Toluene	Yes	No	Aquifer, perched Soil/borehole (vapor) Air	1987–93 1987, 92 1994	Large quantity identified in waste for the historical period; detected frequently in monitoring program
Trichloroethylene	Yes	No	Air Aquifer, perched Soil/borehole (vapor) Sedimentary interbed	1987, 89 1987–93 1987, 92 1987	Very large quantity identified in historical waste; detected frequently in monitoring program
Metals					
Antimony	Yes	No	Perched	1988, 93	Small quantity identified in waste for the historical period; detected rarely in monitoring program
Arsenic	No	Yes	Aquifer, perched	1987–88, 93	Only small quantity identified in waste for recent period; detected rarely in monitoring program

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Metals (continued)					
Barium	No	No	Perched water Sedimentary interbed	1988, 93 1987	Not identified in waste; detected rarely in monitoring program
Beryllium	Yes	Yes	Perched water Subsurface soil Sedimentary interbed	1988, 93 1991 1987	Very large and large quantities in inventory for the historical and recent periods, respectively; detected occasionally
Boron	No	No	Surface soil	1982	Not identified in inventory; not on lists of hazardous substances; detected rarely
Cadmium	Yes	Yes	Perched water Surface soil	1988, 93 1982	Large and small quantities of waste identified in historical and recent period, respectively; detected rarely
Chromium	Yes	Yes	Surface water Aquifer, perched Soil Sedimentary interbed	1986 1985–87, 93 1982 1987	Moderate and small quantities of waste identified in historical and recent period, respectively; detected occasionally
Cobalt	No	No	Perched water	1988, 93	Not identified as a nonradiological contaminant in waste; detected rarely in monitoring program
Copper	Yes	Yes	Perched water Soil Sedimentary interbed	1988, 93 1982 1987	Small and moderate quantities of waste identified in historical and recent period, respectively; detected occasionally
Lead	Yes	Yes	Perched water Surface soil	1988, 93 1982	Very large quantities identified in inventory for both periods; detected rarely
Mercury	Yes	Yes	Perched water Subsurface soil[f] Sedimentary interbed Soil vapor	1988, 93 1991[f] 1987 1990	Large and small quantities of waste identified in historical and recent period, respectively; detected occasionally in environmental monitoring; detected in direct sampling of the Acid Pit

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952-1983)	Contaminant present in inventory? (recent period 1984-1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Metals (continued)					
Nickel	Yes	No	Perched water Sedimentary interbed	1988, 93 1987	Moderate quantity identified in waste for historical period; detected rarely in monitoring program
Selenium	No	No	Sedimentary interbed Subsurface water, perched	1987 1987, 88 1993	Not identified in waste; detected rarely in monitoring program
Silver	Yes	No	Perched water Sedimentary interbed	1988, 93 1987	Moderate quantity identified in waste for historical period; detected rarely in monitoring program
Thallium	No	No	Perched water Sedimentary interbed	1988, 93 1987	Not identified in waste; detected rarely in monitoring program
Tin	No	No	Perched water Sedimentary interbed	1988 1987	Not identified as a nonradiological contaminant in waste; detected rarely in monitoring program
Vanadium	No	No	Perched water Sedimentary interbed	1988, 93 1987	Not identified in waste; detected rarely in monitoring program
Zinc	No	No	Perched water Surface soil Sedimentary interbed	1988, 93 1982 1987	Identified in waste inventory only in radioactive form (<1 g mass); detected rarely
Other					
Chloride	Yes	No	Aquifer, perched Surface soil	1979, 82-93 1982	Very large quantity identified in waste for historical period; detected frequently in monitoring program
Cyanide	Yes	No	Perched water Sedimentary interbed	1988 1987	Small quantity identified in waste for historical period; detected rarely in monitoring program

Table 6-8. (continued).

Contaminant	Contaminant present in inventory? (historical period 1952–1983)	Contaminant present in inventory? (recent period 1984–1993)	Environmental media in which detected[a]	Years detected[b]	Conclusion[c,d]
Other (continued)					
Nitrate	Yes	No	Aquifer, perched Surface water Soil	1982–83, 85, 87, 93 1980–82 1980–83	Very large quantity identified in waste for historical period; detected frequently in monitoring program
Sodium ion	Yes	No	Aquifer, perched Surface water	1979, 82–93 1983–86	Very large quantity identified in waste for historical period; detected frequently in monitoring program
Sulfate	Yes	No	Perched water	1985, 88, 93	Very large quantity identified in waste for historical period; detected occasionally in monitoring program
Sulfide	No	No	Sedimentary interbed	1987	Not identified in waste; detected rarely in monitoring program

a. Subsurface water includes samples from five wells that sample aquifer water and from one well that samples perched water. Separate entries are indicated where possible.

b. Data obtained by EG&G Idaho, Inc. routine monitoring before approximately 1983 are considered to be of lower reliability because, in many cases, no control samples were collected or the control samples were from inappropriate locations. In many cases, contaminants detected in these early samples may have originated in the airborne or waterborne emissions from other INEL facilities rather than from the SDA.

c. The following method was used to express quantitative inventory values using a set of qualitative terms. The expression E+03, for example, covers entries between E+03 and 9.9E+03. Radiological contaminants—Alpha-emitters: Very large=E+04 and greater, Large=E+03, Moderate=E+02, Small=E+01 and less; Beta/gamma-emitters: Very large=E+05 and greater, Large=E+04, Moderate=E+03, Small=E+02, Minute=E+01 and less. Nonradiological contaminants—Very large=E+07 and greater; Large=E+05, E+06; Moderate=E+03, E+04; and Small=E+02 and less.

d. The frequency of detection is expressed in a qualitative hierarchy of terms: frequently, occasionally, rarely. The determination of the appropriate term is based on technical judgment after considering (a) the number of years in which the contaminant was detected and (b) the number of years in which the contaminant was monitored.

e. During 1984 through 1993, no organic contaminants were disposed of in the SDA.

f. Mercury was sampled for in one SDA trench in 1990 but was not detected. Mercury was sampled for and detected in the Acid Pit.

As stated previously, contaminants detected in monitoring at the SDA might not have migrated from the buried waste. This could be the case, for example, with contaminants that are detected only in the aquifer. As another example, U-234, U-235, and U-238 are detected from time to time at the SDA. However, these radionuclides also occur naturally. Only a carefully constructed set of control samples will discriminate as to the likely origin of these three detected radionuclides, between the naturally occurring source and the source within the buried waste. It is beyond the scope of this document to provide definitive determinations on the source of the contaminants detected in the monitoring. The purpose of the present comparison is a simple check to help ensure that the inventory has not omitted any contaminants whose possible presence in the buried waste is manifest by environmental monitoring data.

The following radiological contaminants were detected only in the years before improved routine monitoring began, about 1984 (as discussed in Appendix F, these detections are questionable): Ac-228, Ag-110, Ba-140, Ce-141, Ce-144, Cr-51, Eu-155, Fe-59, Hf-181, Hg-203, I-131, Mn-54, Nb-95, Pb-212, Ru-103, Ru-106, Sb-124, Sc-46, Ta-182, U-237, Y-91, Zn-65, and Zr-95. There are no known, reliable monitoring data suggesting the migration of these contaminants at the SDA. This conclusion is not surprising because many of these contaminants have extremely low mobilities (being trapped in metal matrices), have very short half-lives, and are present in relatively small amounts.

The historical inventory contains a large activity of Pu-241, and this radionuclide is not monitored. The reason is that Pu-241, a beta-emitter, is less radiotoxic than the alpha-emitting plutonium and americium radionuclides that are monitored (Pu-238, Pu-239/240, and Am-241). Plutonium-241 is more difficult to measure and is also much shorter-lived than the other radionuclides mentioned.

6.3.6.2 Nonradiological Contaminants. Routine monitoring for nonradiological contaminants at the RWMC began in the mid- to late 1980s. All of the data for nonradiological contaminants are considered sufficiently reliable for use in these comparisons.

Ten of the fourteen organic contaminants that were detected in the monitoring are listed in the historical inventory. Those not specifically listed in the inventory are 1,1-dichloroethylene, 1,1-dichloroethane, dichlorodifluoromethane, and phenol. (However, phenol was detected only rarely—it was detected in the aquifer once in 1991.) The frequent detections were in both aquifer water and perched water. Any contaminants detected only in the aquifer could have originated at other upgradient INEL facilities. However, any contaminants detected in perched water could have originated in the buried waste.

Several possible explanations exist as to why some of the organic contaminants were detected in the monitoring but not identified specifically in either this inventory or other inventory reports. First, the waste information on which the inventory is based could simply be incomplete. Second, the contaminants could have been secondary species in a waste stream wherein only the primary species were identified. Third, the contaminants detected in the monitoring could be degradation products originating from a contaminant that is listed in the inventory. Three of the organics are very similar in molecular structure to organic compounds that have been identified in the inventory in large quantities; 1,1-dichloroethylene is similar to trichloroethylene, 1,1-dichloroethane is similar to

1,1,1-trichloroethane, and dichlorodifluoromethane is similar to 1,1,2-trichloro-1,2,2-trifluoroethane. Therefore, there is a strong possibility that these are impurities or degradation products of substances that are listed in the inventory. It is beyond the scope of this comparison to distinguish definitively among these possible explanations for the fact that three organics were detected more often than rarely in the monitoring but not identified specifically in the inventory. The conclusion is that nearly all of the organic contaminants detected in the monitoring were identified in the inventory for the historical period.

Among the metals, only beryllium, chromium, copper, and mercury have been detected more than once or twice in the monitoring. All of these metals were identified in the inventory, in quantities ranging from small to very large for both the historical and recent periods. Several other metals have been detected once or twice in the monitoring: cadmium, lead, zinc, antimony, arsenic, cobalt, barium, nickel, selenium, silver, thallium, tin, boron, and vanadium. The measured concentrations approximate natural background levels in many cases. Some of these metals have been identified in the inventory for both the historical and recent periods. The conclusion is that the entire inventory includes all toxic metals that have been detected in the environment on more than rare occasions and at concentrations well above natural background.

The last class of nonradiological contaminants monitored is certain inorganic species. Sodium ion, chlorides, sulfates, and nitrates are detected occasionally to frequently by monitoring; they are listed in the inventory for the historical period in various forms and in very large quantities. Sulfides were detected once in the monitoring, but they were not identified in the inventory for either time period. Again, these detected contaminants could have originated from naturally occurring sources or from the waste. Cyanide has been detected on two occasions and is identified in the inventory for the historical period in a small quantity.

6.3.6.3 Conclusions. No radiological contaminants that were reliably detected in the monitoring are missing from the waste inventory.

For the nonradiological contaminants, other than rare detections or detections at concentrations near natural background levels, no metals or other inorganics on the list of hazardous substances were detected in the environmental monitoring but not listed in the inventory for one of the two time periods. Ten of the fourteen organic contaminants that were detected in the monitoring are listed in the inventory for the historical period. The other four organic contaminants may be degradation products or impurities of contaminants that were identified in the inventory for the historical period or may have originated from other INEL sources.

6.4 Contaminant Profile Data Sheets

Appendix G presents the contaminant inventory in a simple yet informative form, on contaminant profile data sheets. The data sheets provide a quick reference summary for most of the principal contaminants. Data sheets were prepared for contaminants that were among those present in the largest quantities.

Each contaminant profile data sheet briefly lists typical contaminant physical and chemical forms and properties, common uses, general presence in the environment, toxicology, the amount disposed of at the SDA, and the results of environmental monitoring at the SDA. For radiological contaminants, the radiological properties and radiotoxicity are also included.

References for Section 6

Cerven, F., 1987, *Estimate of Hazardous Waste Constituents in the RWMC Subsurface Disposal Area*, Engineering Design File TWT-010-87, EG&G Idaho, Inc., December 1987.

ChemRisk, 1992, *Reconstruction of Historical Rocky Flats Operations and Identification of Release Points*, Projects Tasks 3 and 4, Chemrisk, A Division of McLaren/Hart, Alameda, California, August 1992.

Duncan, F. L., J. A. Sondrup, R. E. Troutman, 1993, *Remedial Investigation/Feasibility Study Report for the Organic Contamination in the Vadose Zone—Operable Unit 7-08, Volume I: Remedial Investigation*, EGG-ER-10684, EG&G Idaho, Inc., December 1993.

EG&G Idaho (EG&G Idaho Inc.), 1989, *Remedial Investigation/Feasibility Study Work Plan for the Subsurface Disposal Area Radioactive Waste Management Complex at the INEL*, draft, EGG-WM-8776, December 1989.

EPRI (Electric Power Research Institute), 1987, *Updated Scaling Factors in Low Level Radwaste*, EPRI NP-5077, Impell Corporation, March 1987.

Figueroa, I. del C. et al., 1992, *Baseline Risk Assessment for Pit 9 Located at the Subsurface Disposal Area*, draft, EGG-ERD-10261, May 1992.

Garcia, E. C., and J. Knight, 1989a, "EPA Toxic and Ordinary Metal Content in Pit 9," Engineering Design File BWP-ISV-001, January 1989.

Garcia, E. C., and J. L. Knight, 1989b, "Detailed Estimate of Radioactive Material Contents for Pit 9," Engineering Design File BWP-ISV-004, February 1989.

Garcia, E. C., S. M. Thurmond, J. Knight, 1989, "Estimate of Metal Content of SDA," Engineering Design File BWP-ISV-005, EG&G Idaho, Inc., January 1989.

Jorgensen, D. K., 1992, *Draft Final WAG-7 Acid Pit Summary Report*, EGG-ERD-10242, EG&G Idaho, Inc., September 1992.

Halford, V. E., O. R. Perry, W. C. Craft, III, J. J. King, J. M. McCarthy, I. D. Figueroa, Y. McClellan, 1993, *Remedial Investigation/Feasibility Study for Pad A, Operable Unit 7-12, Waste Area Group 7, Radioactive Waste Management Complex, Idaho National Engineering Laboratory*, EGG-WM-9967, EG&G Idaho, Inc., Revision 1, July 1993.

Kudera, D. E., 1987, "Estimate of Rocky Flats Plant Organic Wastes Shipped to the RWMC," internal note, EG&G Idaho, Inc., July 24, 1987.

Kudera, D. E., 1994, letter to W. H. Sullivan, "Historical Rocky Flats Plant Information on Plutonium Losses to Burial," DEK-04-94, EG&G Idaho, Inc., March 28, 1994.

Lee, W. H., 1971, letter to H. F. Soule, "Rocky Flats Solid Waste Shipped to NRTS," June 10, 1971.

Liekhus, K. J., 1992, *Nonradionuclide Inventory in Pit 9 at the RWMC*, EGG-WM-10079, EG&G Idaho, Inc., January 1992.

Litteer, D. L., V. C. Randall, A. M. Sims, K. A. Taylor, 1993, *Radioactive Waste Management Information for 1992 and Record-To-Date*, DOE/ID-10054(92), U.S. Department of Energy, July 1993.

Nieslanik, R. W., 1994, letter to T. H. Smith, "NRF Comments to the Radioactive Waste Management Complex (RWMC) Waste Inventory Report," NRFEM-RR-1122, Naval Reactors Facility, March 29, 1994.

Plansky, L. E. and S. A. Hoiland, 1992, *Analysis of the Low-Level Waste Radionuclide Inventory of the Radioactive Waste Management Complex Performance Assessment*, EGG-WM-9857, Revision 1, EG&G Idaho, Inc., June 1992.

Wilhelmsen, R. N., K. C. Wright, B. W. McBride, 1994, *Environmental Surveillance for EG&G Idaho Waste Management Facilities at the Idaho National Engineering Laboratory*, EGG-2679(93), EG&G Idaho, Inc., August 1994.

7. OBSERVATIONS AND CONCLUSIONS

Based on the results and knowledge gained in compiling the inventory, the following observations and conclusions are presented:

- The combined use of many types of information sources—process knowledge, operating records, technical calculations, reports, interviews, shipping records, the RWMIS database, and others—was essential to achieve the present degree of completeness of the inventory.

- For radiological contaminants, the inventory information that could be located and that is compiled in the new CIDRA database is believed to be substantially complete.

- For nonradiological contaminants, the inventory information that could be located and that is compiled in CIDRA is also believed to be substantially complete. During the time period of interest, strong emphasis was not placed on documenting the nonradiological hazards in the waste because the current requirements for reporting hazardous chemicals did not exist. However, process information gathered from a multitude of sources has resulted in closing most of the gaps in the shipping records.

- A substantial effort was devoted to breaking down the generic radioactivity terms MAP, MFP, unidentified alpha-emitters, and unidentified beta/gamma-emitters for each generator so that a specific distribution of radionuclides would be available for the risk assessment.

- The predominant (by mass) nonradiological contaminants identified in the waste were as follows: metals—lead, zirconium and its alloys, beryllium, magnesium, sodium-potassium, cadmium, and mercury compounds; organics—carbon tetrachloride, 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, and methylene chloride; acids; nitrates and other salts; and asbestos.

- The predominant (by radioactivity at the time of disposal) radiological contaminants identified in the waste were Fe-55, Co-60, H-3, Ni-63, Cr-51, Cs-137, Sr-90, Pu-241, Mn-54, Co-58, Ce-144, and Am-241.

- To confirm its completeness, the compiled inventory of radiological contaminants was compared against the corresponding inventory in the RWMIS database. For the principal radionuclides, the agreement with RWMIS was generally within the total random error of the usual activity-measurement method except for two instances in which the present task developed major new information:

    - The estimated H-3 activity is approximately 20 times larger than the RWMIS value, due primarily to the identification of a major TRA waste stream with approximately 1 million Ci of H-3 entrapped in beryllium.

    - The estimated activities of plutonium and americium radionuclides increased typically by a factor of 10 over the RWMIS values. This result stemmed from an extensive effort to obtain new information on the RFP waste, based on a plantwide inventory balance at the RFP.

- As an additional confirmation of its completeness, the compiled inventory of radiological and nonradiological contaminants was compared against the inventories in previous reports. The list of contaminants in the new inventory is considerably longer than those in previous inventories. For nearly all contaminants, the new inventory values are similar to or larger than those in previous inventories. Possible exceptions are asbestos, sodium hydroxide, and zirconium, but the methods of estimating quantities of the contaminants vary from study to study.

- As a final confirmation of its completeness, the present inventory of contaminants was compared against the list of contaminants detected in environmental monitoring at the RWMC. No radiological contaminants were reliably detected in the monitoring that had not been identified in the inventory. The only nonradiological contaminants detected more than rarely in the environmental monitoring that were not identified in the inventory were three organic compounds: 1,1-dichloroethylene, 1,1-dichloroethane, and dichlorodifluoromethane. These three contaminants may be degradation products or impurities associated with closely related contaminants that were identified in the inventory. Detected contaminants also could have originated from sources other than the subject waste, e.g., in effluents from other INEL facilities or from other waste at the RWMC.

- A large quantity of information was assembled and entered into CIDRA on the physical and chemical forms of the waste streams and of the contaminants, as well as on the packaging of the waste streams.

- Even though the information now residing in CIDRA has been through multiple checks and reviews, the possibility exists for oversights and discrepancies. As new information is discovered, the database will be revised as necessary.